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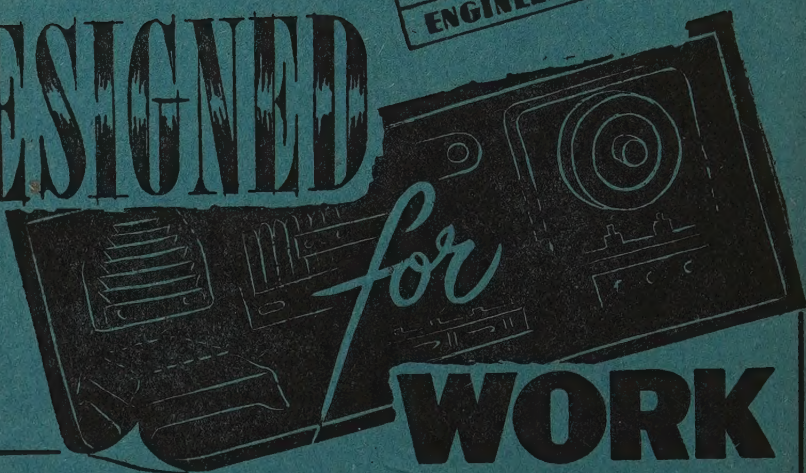
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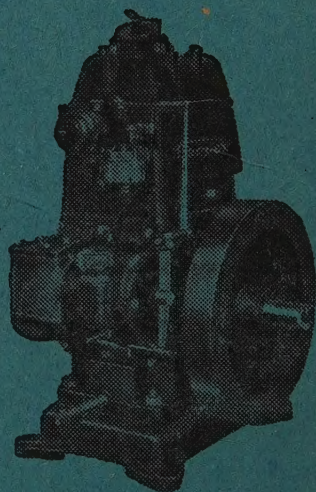


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MARCH, 1951.

No. 1.

**A REVIEW OF THE APPLICATION OF STATISTICAL
TECHNIQUES TO WHEAT AGRONOMY IN
AUSTRALIA**

By

E. R. WATSON, Geneticist and Cereal Research Officer.

INTRODUCTION.

AGRONOMY was practised as an art for many centuries before it was realised that reliable information was required to answer the problems of agriculture. With this realisation, agronomy gradually became a science; gradually in the respect that at first the numerous problems were tackled in a rather disorderly approach, and yet rapid in that a vast amount of scientific knowledge was accumulated in less than a century. The rapidity with which the knowledge was accumulated was made possible by the fact that the empirical knowledge gained by pioneer workers was quickly supplemented by organised research which provided the necessary fundamental information.

Recent advances in statistical methods have practically revolutionised the technique of field experimentation, so that at present this branch of research has become an exact science in comparison with its previous rather empirical status. While improvements have taken place in the actual field technique of experimentation, a still more important development has been an improvement in the methods of the final evaluation of the data obtained.

In the development of statistical technique in experimentation it has become obvious that there is no easy road to success and that every problem tackled is of necessity a complex one, on account of the number of interacting factors that have to be considered before arriving at any definite conclusions. Soil and seasonal heterogeneity are two of the most important factors to be considered.

Field trials generally are not of the nature of fundamental research, but are planned essentially from the utility viewpoint as a means of improving cultural practice in one direction or another. Field trials should be the final stage in the solution of any given agricultural problem and should be resorted to only after the simpler and less expensive method of eliminating any obviously unsatisfactory practice has been utilised. For example it would be of little value to conduct exacting field trials as a step towards improvement in a primitive agricultural community where the general principles of good cultivation were continually flouted. The obvious approach to such conditions would be the establishment of a higher standard of field practice with a more intelligent appreciation of the elementary laws of crop growth.

Within recent years there has been a tendency on the part of some investigators to adopt very complex experimental designs when the problem has been rather simple and fundamental, under the mistaken impression that the more complex the design the better the results. An examination of the development of statistical technique shows that the more complicated experimental layouts and methods of analysis of the results obtained from them have developed with the need for such designs to meet the requirements for solving certain sets of questions. At all times it should be remembered that the problems of agriculture are essentially practical, which necessitates a practical approach to their solution. The field experimentalist has to contend with many problems and Engledow's quotation "Alice soon came to the conclusion that it was a very difficult game indeed" should prove to be a steadying influence when the experimentalist tends to make his work even more difficult than the problem requires.

HISTORY OF FIELD EXPERIMENTATION.

A study of the history of field experimentation shows that the science of agriculture began and developed simultaneously with the establishment and development of experiment stations. The credit of establishing the first experimental station is due to Jean Baptiste Boussingault who first undertook field experiments on a practical scale at Bechelbronne, Alsace in 1834. The nature of his research can be regarded highly in the light of modern knowledge. His classical investigations concerned the source of nitrogen in plants, and the effects on plants when legumes were included in the rotation.

Rothamsted Experiment Station.

The Rothamsted Experiment Station was established by John Bennet Lawes on his farm in England in 1841. Hall (1905) in his account of the Station stated that "Rothamsted is now a household word wherever the science of agriculture is studied." The important

discoveries concerning the value and manufacture of phosphatic fertilisers led to large scale experimentation. The systematic experiments begun in 1843 are still continued and have served for many years as models of carefully planned experiments. In 1843 Lawes was joined by Dr. J. H. Gilbert and the two men worked together for 57 years. More recently Dr. R. A. Fisher has been responsible for modifications in the field experiments to make them amenable to statistical treatment.

The results of the experiments at Rothamsted have been summarised a number of times. On the first occasion in 1893 Lawes and Gilbert summarised the results of their 50 years of experiments. The work had been entirely their own and as they had had no collaboration with scientific investigators trained in other fields the results were presented from a single point of view only. The summary of the experiments set out by Hall (1905) also represented a single viewpoint although Hall had benefitted from discussions with other scientists with other outlooks.

The development of statistical methods of analysis enabled further information to be extracted from the available data, and allowed the connection between various sets of observations to be traced. This replaced the intuitive processes by which Lawes and Gilbert arrived at their rules and generalisations. Their method of examination of data was based mainly on the inspection of averages over a period of from five to ten years. The original material collected by them had the advantage of being simple and easily translated into farming practice.

Russell and Watson (1940) realising the necessity for a summarisation of the newer material available, presented a full summary of the work which had been carried out at Rothamsted including the earlier findings of Lawes and Gilbert, and Hall. This summary of necessity lacked the simplicity of the earlier presentations, as advantage was taken of statistical methods in the derivation of information.

In recent years a great deal of stress has been placed on the design of experiments. The field layout and the method of analysis of data are now co-ordinated so as to lead to more efficient experimental results. Particular emphasis has been placed on design by the Rothamsted workers as they believe that design more than any other aspect directs attention to the objects of an experiment.

American Experiment Stations.

The general movement for the establishment of experiment stations in America began about 1871 due to the attention attracted by the experiments of Lawes and Gilbert in England.

In 1875 California established the first experiment station where field experiments concerning deep and shallow ploughing for cereals were commenced. The Hatch Act passed by Congress in 1887 marked the commencement of the present day system of experiment stations. At present the Federal Government controls funds given to the States for experimental work and a system of participation and co-ordination rather than control has proved satisfactory.

History of Development in Australia.

It is unfortunately true that much of the history of the earlier development of agriculture in this country has not been fully recorded with the result that much of value has been forgotten or lost.

Although there are references to various experiments which were carried out in the various States since the latter part of the last century the actual thread of the development of experimental technique in Australia has never been fully recorded, resulting in gaps in the knowledge which may be difficult to fill.

The writer is indebted to Dr. G. L. Sutton, who has been associated with much of the development of agriculture in Australia, for a great deal of the following information.

Although experimentalists in Australia had the advantage that the development of field experimentation techniques coincided to a large degree with the development of agriculture in this country, there was, prior to 1900, very little in the way of true experimentation. Comparison of varieties or treatments was based mainly on adjacent acre plots. Sometimes the plots were considerably larger than an acre and quite often they were not adjacent but in separate paddocks and the only direct unit of comparison was the area harvested. Field experimentation was then at a very low level and the development in the following 30 years was in the main the result of the energetic approach to the problem by a few of the early experimentalists.

One of the earliest records of systematic experimentation is provided by Sutton (1903) regarding an experiment suitable for farmers to determine preliminarily the necessity for the use of commercial fertilisers on their properties. Sutton, who was at the time experimentalist at Hawkesbury Agricultural College in New South Wales, wrote as follows:—"A piece of ground fairly representative of the land under consideration, should be selected. Mark off accurately a series of plots 10 in number and each $\frac{1}{20}$ th of an acre. If desired the plots can be extended so as to include any area but it is desirable that the plots should not be less than $\frac{1}{20}$ th acre each. For $\frac{1}{20}$ th acre plots a convenient size is 198 feet (3 chains) long by 11 feet ($\frac{1}{6}$ th chain) wide, though it is not essential that plots be of the dimensions stated but may be altered to suit local circumstances. Yet it is desirable that the plots be long and narrow so as to include as many inequalities of the soil as possible."

This record is interesting in that it illustrates a number of important points. Firstly with regard to plot size, there was a reduction from the acre or more unit to the smaller $\frac{1}{20}$ th acre plot. Secondly there was the introduction of the long narrow plot. Sutton's aim in all his experimental work was to have as narrow a plot as practical, for the reasons he stated above. Working with maize and potatoes he utilised the single row unit, while for wheat trials he introduced the drill unit which has been used extensively throughout Australia since that time. Another important point about this experiment was that the various treatments could be compared with plots which had received no treatment.

In the same season at Hawkesbury, Sutton used a variety of maize of known yielding ability as a control variety for a comparison with other varieties of unknown yielding ability. The practice of utilising a variety of known yielding ability as a control has now become of universal acceptance and its value is appreciated by the experimentalist and the farmer alike.

Describing these trials Sutton (1903) wrote "Each (maize) variety under trial was planted between two adjacent drills of the standard variety Red Hogan. The yield of each variety can thus be compared with the average yield of the variety growing on either side of it. By expressing the average yield of these two drills as 100 the actual yield of the other varieties can be given as a percentage of Red Hogan. By comparing these percentages with each other it is thought a much better idea of the actual merit of the different varieties will be obtained than by comparing the varieties with each other. Owing to the unevenness of the ground and to other causes it is often found that the difference in different parts of the same plot is greater than the difference between two distinct varieties."

At that time the Pathologist of the New South Wales Department of Agriculture was Dr. N. A. Cobb who was an American and regarded by Sutton as being the first true agricultural scientist in Australia. When Sutton met Cobb while making arrangements to have the results of his 1902 experiments published, he was congratulated by him for using a control variety in his experiment. Cobb said, "I want to congratulate you on your experiments. You have broken new ground by the use of control plots which are a yardstick to measure the performance of the other varieties." These two experiments were probably the first move in the direction of the now generally accepted system of comparing varieties or treatments of unknown capacity with one of known capacity. Cobb had a very definite influence on Sutton and his work, as he was the first man to indicate to experimentalists that field experiments should not be haphazard arrangements but governed by definite rules.

William Farrer, who had contributed so much to Australian agriculture, realised one of his ambitions when the Cowra Experiment Farm was established in 1905. This enabled him to carry out experimental work relating to soil fertility. In that year, in association with Sutton, he designed and carried out an experiment which dealt with a comparison of three varieties of wheat, at three rates of seeding, at three times of planting with a complete factorial fertiliser design including no fertiliser, phosphate, nitrogen and potash, singly and in all possible combinations. Prescott (1948) is of the opinion that the experiment conforms in conception and statistical design (except for randomisation) with the best of present day ideas of what such an experiment should be.

Farrer's death in the following year was a sad loss to Australian agriculture. Although many of his ideas were passed on to and practised by his successors, it is probable that had he lived, Farrer would have been responsible for a considerable amount of improvement in experimental methods in Australia.

In his 1902 experimental layout Sutton suggested the use of every fifth plot as a check with four variants between check plots. In his maize trial, however, Sutton unconsciously used an experimental layout, the design of which was not advocated until some 20 years later. Although not identical the layout was very similar to that recommended by Beaven in 1922.

The single plot system was continued for many years with a number of minor modifications. The first was an increase in the number of control plots so that there were only three variants between each control. A later modification was made in approximately 1910 when, on a suggestion by Professor Thorn of America, Sutton introduced the system of calculation of probable or "natural" yields. Prior to this, Sutton had suggested the use of the percentage basis of comparison whereby the control variety was regarded as 100 per cent. and the variants expressed in percentage above or below that figure. The method of calculation of "natural yield" was a system of interpolation of the probable yield of controls in the intermediate positions, with the per cent. yield of the variants based on this theoretical or calculated yield.

After Sutton's appointment as Commissioner for the Wheatbelt in Western Australia in 1911 the Three Plot system of field experiments was adopted in this and other States. This system obviated the necessity for the calculation of probable yields as it enabled a direct comparison between each variant and the control. Apart from the later introduction of replicating each block five times the Three Plot system found general favour, and was used extensively throughout Australia. The Beaven Half-drill-strip method on its introduction was favoured in some States, and was used to some extent, as was the modified Half-drill-strip method. This was, for all practical purposes, the same as the Three Plot system, except that in the latter system the drill, rather than the half drill, was the unit.

Although experimentalists were probably aware of the necessity to improve experimental techniques and interpretation, the work of Forster and Vasey (1928) confirmed, under Australian conditions, the results obtained in other countries, and directed attention very forcibly to the subject. The publication of their paper in 1928 can probably be regarded as the commencement of a new phase in field plot technique in this country.

In a later paper (1932) the two investigators drew attention to more recent developments and summarised the position regarding the Analysis of Variance method for interpretation of results obtained from randomised block experiments. Although their article did much to elucidate the position, and presented to experimentalists a simplified explanation of the statistical terms and methods required, the randomised block layout did not find immediate favour in some States. The method presented some difficulties both in the field layout and in the interpretation of the results. Its advantages however were too numerous to be disregarded and it gradually replaced most other designs. At present it is probably the most widely used method of field experimentation in Australia. The more complex designs such as the Latin Square and Lattice Square layouts have been favoured for some specialised sections of agricultural experimentation, but for general experimental work the Randomised Block layout has proved to be very acceptable.

EXPERIMENTAL ERRORS.

In any experimental work consideration has to be given to two main kinds of errors—systematic errors and chance errors. These are to be distinguished from actual mistakes made by the experimentalist. Systematic errors are those that occur every time an experiment is repeated in the same manner, while chance errors represent those which occur by pure chance and are generally small fluctuations due to minor causes. Although it may be possible by experimental design, or some other means, to control systematic errors, it is usually necessary to employ statistical methods in field experiments to measure the effect of chance errors. The sources of error in experimental work can usually be contributed to either faulty design and inferior technique or an improper interpretation of the results.

It is necessary, however, to give consideration to variations in field experiments as well as error. The most common can be classed as plant, seasonal and soil variations. A well designed experiment will enable the variations that cannot be balanced out to be measured, and while it is possible to balance part of those due to defined causes such as soil heterogeneity it may not be possible to balance them entirely. The variations due to unrecognised causes are measured and assigned to experimental error.

The statistical method is the mathematical means of measuring and describing variation and allocating its component parts to certain recognised sources. The use of an experimental design which takes into account the recognisable sources makes the quantitative measurement of variation possible. By measuring total variation it is possible to obtain a measure due to all uncontrollable sources. Statistical method provides a means of comparison between the obtained quantitative measures of variation due to recognised possible causal factors, with that portion classified as error, thus enabling conclusions to be drawn in regard to the relative importance of the various sources.

In the earlier days of the development of experimental technique there was not the appreciation of experimental error that exists today, with the result that it was neglected or disregarded both in the design of the experimental layout and in the final analysis of results which quite often caused an incorrect interpretation of the results. This fact has been shown by the application of more modern methods of statistical analysis to the results of experiments carried out in previous years, followed by a comparison of the conclusions derived from the data.

In their paper entitled "Experimental Error of Field Trials in Australia" Forster and Vasey (*loc. cit.*) draw attention to the classical experiment of Hall and Mercer which they repeated at the State Research Farm, Werribee, Victoria. The experiment was undertaken to determine—

- (i) The variation in an apparently uniform acre of wheat as measured by the "Standard Deviation" and the "Probable Error" of 1/160th acre plots.

(ii) The optimum—

- (a) size;
- (b) shape;
- (c) number of plots necessary to reduce this error to a minimum.

Taking what was considered to be a uniform acre of "Free Gallipoli" wheat they divided it into 160 plots which were individually harvested.

The results of these investigations confirmed previous overseas work along similar lines and led the authors to the following conclusions:—

In this field experiment there are two types of error—

- (a) casual error due to small chance errors in harvesting technique, uneven seeding, manuring, hare tracks, etc. These may be so gradual as to be unappreciable to the eye;
- (b) more regular errors due to marked soil variations, climate, etc.

The important fact demonstrated by the experiments was that the frequency curve of the yields of the 1/160th acre plots agreed with the normal curve of error which allowed certain statistical formulæ to be employed to estimate the variation of the results. The conclusions regarding the optimum size, shape and number of plots will be considered later.

In a later paper (1932) the two authors discussed the types of variation which occur in a trial conducted on a block basis. A consideration of the variation of each plot from the general mean of all the plots regardless of treatment or position indicates the total variation within the experiment. This total variation can be allotted a number of components, namely—

- (a) the variation due to different varieties or treatments;
- (b) the variation due to gradual soil gradients from side to side of the field;
- (c) the random causes of variation due to the smaller patchy effects of soil and other factors.

No attempt will be made at this stage to comment on the actual error due to these component sources of variation, as this aspect will be discussed as the various experimental layouts are compared. The development of statistical methods of analysis however, followed the realisation of the need to obtain a real value of the different types of variation by a sound statistical method, and thus to determine the relative importance of each component in the experiment.

One of the most important developments in statistical technique was that the principles enunciated by both "Student" and Fisher were concerned with the recognition of these variations and the actual determination of values to be allotted to them. The method has been termed the analysis of variance since the total variation or variance is analysed into its component portions. The variation due to random causes is the measure of the "error" of the experiment and a difference is considered as significant when the variation due to treatment is significantly greater than that due to error.

Plot Dimensions.

In the design of experiments various factors have to be taken into consideration concerning the optimum size, shape, and number of plots necessary to reduce experimental error to a minimum.

The Size of Plots.

The size of plots in relation to experimental error was first studied at Rothamsted in 1910 by Mercer and Hall. As a result of their investigations and those conducted subsequently by other workers, the trend has been towards smaller plots and increased replications. Plot size now ranges to as small as 1/1000th acre with an increasing tendency to abandon the large plot system.

Apart from the accuracy of the results desired, there are a number of factors influencing the optimum plot size for a particular experiment. The type of crop for instance will influence plot size, as the aim should be to carry a large enough population to be representative of the crop to be tested. A second consideration is the number of varieties or treatments to be tested. In plant breeding projects for instance, it may be necessary to test a large number of crossbreds of which only a limited supply of seed is available. This will necessitate the use of small plots both from the point of view of convenience of size of the experiment and the limit placed by the available seed.



Randomised block design.—A large scale (one-eighth acre plots) cereal variety trial on a wheatbelt research station. The plots are 15 links wide by 10 chains long. A buffer at each end has been removed to reduce the plots to 833 links in length.

Forster and Vasey (loc. cit.) came to the following conclusions as a result of their investigations:—

- (i) The casual error attaching to a single plot decreases with the increasing size of the plot, but the more systematic error of soil variation becomes more important as the plot increases in size.
- (ii) The optimum size of field trials for cereals under conditions such as these (Werribee, Victoria) is 1/40th acre.

- (iii) That there would appear to be grounds for the belief that a long narrow plot is the more desirable for field trials.
- (iv) That the error attaching to a $1/40$ th acre plot is diminished to a working minimum by a replication of five times in any one series. These conclusions confirmed the findings of workers in other parts of the world.

Throughout Australia, at present the $1/40$ th acre plot is adopted for cereal trials except in this State where an $1/8$ th acre plot is generally utilised. There is the danger with large plots that the area of the trials will become too extensive, with the soil variants becoming increasingly important. The tendency to increase the number of replications rather than the size of the individual plots is an important trend from the statistical point of view. In any experiment, however, the crop, the soil, the object of the experiment, planting and harvesting machinery and labour available should all be taken into consideration.

Shape of Plot.

Investigators conducting uniformity trials noticed in some instances definite soil fertility gradients within an area. Plot shape is influenced in most instances by the necessity to best overcome the effects of soil heterogeneity. Whereas some investigators have found that long narrow plots best overcome these effects, others believe that plots should be approximately square. Summarising the available evidence it would appear that plot shape exerts little or no influence in accuracy where soil variation is as great in one direction as it is in the other. Where there is, however, a definite soil fertility gradient in one direction only, or in one direction more than in the other, then it would appear to be advisable to design the experiment with the plots having their greatest dimension in the direction of the greatest variation. It is generally conceded that relatively long and narrow plots with the long dimension in the direction of the greatest soil variation best overcome the effects of soil heterogeneity. For the most efficient design however, the area occupied by a single replicate or block should approach a square in shape.

From the practical aspect of seeding and harvesting the shape of the plot will to a certain extent be governed by the implements available. Usually the long narrow plots lend themselves more readily to ease of seeding and harvesting than the square plots. When the direction of the soil gradient is not known it would seem advisable to adopt a design which groups long plots into as compact an area as possible.

The importance of realising the influence of soil heterogeneity on the yields of plots cannot be over emphasised. Soil heterogeneity is universal and many investigations have shown almost without exception that paddocks in which experiments are conducted are so heterogeneous as to influence profoundly the yields of the plots. This stresses the importance of greater care in field plot technique and also the necessity to utilise statistical methods of analysis of the data obtained.

Number of Replications.

The two main factors to receive consideration in this aspect of experimental design are the variability of the material and the degree of precision desired. Soil variability and in some instances the amount of seed available may also be important considerations. The point is, that the most effective method to obtain greater accuracy in field experiments is to increase the number of replications. Frequent replications of small plots has proved to be a more efficient means of obtaining a high degree of accuracy than the use of the same amount of land with less frequently replicated larger plots. It is generally accepted that four to six replications are necessary to measure differences in the order of 10 per cent. For more variable material such as pastures or nursery plots a greater number of replications might be necessary. In the case of randomised block trials where the number of treatments is large, four or five replications are usually considered sufficient.

Seasonal Variations.

When taking into consideration errors of field trials it is extremely important to make allowance for seasonal variations if the results are to be interpreted on a long term basis. Any plot technique can only provide information regarding a variety or treatment on a particular soil type under the given set of climatic conditions, whereas the most suitable variety for a district is the one that gives consistently high yields over a number of seasons. It would be inadvisable to design an experiment that gave one or two per cent. accuracy and be satisfied with the results of one year's trial only.

The error due to seasonal variation is considerable, and has been calculated by Engledow and Yule for cereal variety trials, as being in the region of 8 per cent. The measurement of seasonal variation is rather difficult, since it is practically impossible to repeat a series of plots under exactly similar soil conditions for several years. Planting the plots on exactly the same site each year would be one method if the complicating factor of decreasing yield due to lowered soil fertility did not have to be considered.

It would appear then that the most practical approach to the problem is to repeat any given experiment over a period of years in order to reduce the error due to seasonal variation to a figure comparable to that for soil variation of the particular experiment.

An alternative with some types of trials, e.g., variety trials, is to repeat the trial in one season in a number of localities on similar soils but under different climatic conditions.

STATISTICAL ANALYSIS OF DATA.

The value of the statistical approach to experimental technique can be treated in retrospect to illustrate the inadequacy of the earlier types of experiments in Australia. Apart from several contributions made by Sutton there was little modification of the single plot trials for many years. One notable exception was the experiment designed by Farrer and Sutton which has been mentioned

previously. It was extremely unfortunate that Farrer had only a year preceeding his death to realise one of his ambitions "to conduct field experiments relating to the cultivation of wheat." As it was, his experiment of 1905 stands as a monument to the ability of a man who contributed so much to various phases of Australian agriculture.

The single plot trials which were the only methods of field experimentation in Australia for many years consisted of a number of plots of individual varieties with a control variety interspersed at intervals of every five or ten varieties. Each variety was compared with the nearest control. Before commenting on the statistical application of these trials, it should be noted that this type was in use during years of very great development in Australian agriculture. It is highly probable that this design of experiment was most instrumental in demonstrating the fundamentals which at that time were essential to the development of the country. The size of the plots and their layout were extremely useful factors in demonstrating the value of applications of superphosphate and the failure of basic phosphate to give similar responses, etc. It is doubtful whether any other experimental design is so eminently suited for the purpose of demonstration of fundamental facts to the farming community. It suggests that when the main object of an experiment is to convey to farmers a fundamental fact, then the design of the experiment should be simple with few complicating factors.

The single plots were continued over a number of years and averages obtained for comparison of varieties and treatments. The results were subject to very large variations due to soil and climate differences, etc., and consequently a true interpretation was very difficult owing to the proportionally large differences which were necessary to be of any significance. At that stage of agricultural development however, the improvements affected by fertilisers, new cereal varieties, etc., were usually of such magnitude as to outweigh the variations due to lack of experimental techniques.

An early modification of the single plot system resulted from the realisation of the necessity to randomise plots. Plots were simply randomised over the whole area and often a large number of replications was utilised to permit a dependable estimation of the error of any one variety. The results from these randomised chessboard design experiments were usually separated into groups of the same variety. Although the randomisation of the plots affected some improvement over the previous orderly arrangement, the error due to both soil gradients and casual causes was still large, necessitating substantial differences between varieties before any significance could be recognised.

A similar method had been utilised for many years by Sutton and his associates without perhaps the knowledge of the statistical implication of the design but it was not until 1922 that Beaven advocated the use of what he called the Half-drill Strip method for cereal trials. At the time Beaven was a member of the Council of the National Institute of Agricultural Botany in England. In advocating the method he stated that the object was "to minimise the

effect of divergencies in the conditions external to the plant." He developed this method in connection with trials of new varieties of cereals with a view to securing comparative accuracy in the results of field tests.

The method was apparently based on a fact, demonstrated some 11 years earlier by "Student," that pairs of closely adjacent plots were subject to very similar soil conditions, resulting in a reduction in the "error" of the difference between the members of the pairs. Beaven decided that the variety under test and the control variety could be the members of a pair and that these could be sown from either half of a drill with the central hoe blocked.

With successive runs of the drill the order of the plots would be ABBA, ABBA, etc., where A represents the variety and B the control. The use of this method balanced any effects due to soil gradient from one side of the paddock to the other, as the pairs of plots experienced similar soil conditions. In addition, both members of the pair consisting of the variety under test and the control variety were subject to similar variations in seeding, fertilising, etc.

The two main factors of soil variation were considerably reduced by the use of this method. The pairing of the treatment under trial and the control in adjacent plots was instrumental in reducing the error due to the larger soil patches, while the soil gradient factor was avoided by the balancing of the order of the plots in successive pairs. This constituted a considerable advance in field experimentation, and the method was used fairly extensively in Victoria and to a lesser degree in some other States for a number of years. Beaven maintained that by the use of the Half-drill Strip method the probable error of the difference between the weights of grain of the two races under test could be reduced to about .5 per cent. as compared with over 5 per cent. error when single plots were compared. At Werribee the average Standard Error percentage of a single comparison of two varieties in 18 trials conducted during 1927-30 was about 2 per cent. which compared more than favourably with the 8 per cent. error experienced with the single plot trials.

Two disadvantages of the Half-drill Strip method soon became apparent. Firstly, although it was ideal for testing one variety or treatment against a control, when a number of varieties or treatments were to be compared a number of different trials was necessary and the value of comparison between them was rather doubtful. Secondly, because of the large number of control plots required in each experiment a considerable area of uniform soil was required to test a number of varieties or treatments. The difficulty of obtaining large areas of relatively uniform soil threw some doubt on the value of comparison between different varieties or treatments in different experiments.

An adaption of the method to slightly overcome the first objection was the comparison of two varieties or treatments in the one trial. This was accomplished by sowing the experiments ABC, CBA, etc., where A and C represent the varieties under test and B the control variety. The analysis of the results did not present any great modification on the previous method as A and B and B and C were regarded as pairs to obtain the significance.

It became evident, however, that the alternative to comparing one or at the most two varieties directly with the control variety was the grouping of the varieties into blocks, the replication of each variety being obtained by repeating the whole block a number of times. A method of treatment of the results from such an experiment was suggested by Hayes whereby the percentage variation from the mean of each variety was used in the calculation of the error. This method of estimating the error of the experiment by considering all the plots in the trial was distinctly more valuable than the consideration of a replication of each variety only. It did not take into account soil variation and resulted in a larger error for the experiment than the Beaven method.



A series of randomised block design experiments on a wheatbelt research station. The buffer plots between blocks and the headlands between experiments have been cut out with a binder to insure ease of harvesting.

The convenience of the block layout was however undeniable and the need for a method whereby it would be possible to compare a number of varieties or treatments in one experiment, while taking cognisance of the soil variation factor was appreciated by experimentalists. This led to the development of a method of analysis proposed by Engledow and Yule. They suggested that "Student's" assumption that adjacent plots would experience similar soil conditions could be extended to include all the plots in any one block. The plots were sown in a definite order and in treating the results they first expressed the yields of all the plots of variety A as a deviation from the mean yield of A. The same procedure was adopted for each variety under trial. The differences between the respective pairs of A and B, A and C, B and C, etc., were determined by applying "Student's" principle and then a mean error for the whole experiment was arrived at from the error of each set of differences, with significance determined in the usual manner.

The value of this method, representing a definite improvement in technique, would probably have had much further reaching effects, had it not been proposed at about the same time that an important method of analysis was suggested independently by "Student" and Fisher.

The criticisms of Engledow and Yule's method were that not all conditions allowed for the extension of "Student's" assumption to all plots on a block, and also that the plots being sown in a systematic order did not permit the correct estimate of the random soil variations.

Analysis of Variance.

The types of variation which occur in a trial designed on a block basis have been discussed previously. The principles put forward by both "Student" and Fisher were concerned not only with the recognition of these variations but also with a means of determining their relative values. This resulted in the method being termed the analysis of variance, as the total variance is analysed into its component portions. Differences are considered as significant when the variation due to treatment is significantly greater than that due to error.

With the stipulation that plots be sown entirely in random order Fisher obtained the values for the different components of the total variation. After calculating the squares of deviation from the mean in the usual manner, Fisher then summed them as follows:—

- (a) The total variation—from the sum of the squares of the deviations of all the plots from the general mean.
- (b) The treatment variation—from the sum of the squares of the deviations of the treatment totals from the mean.
- (c) The soil gradient variation—since each block contains one plot only of each treatment the block totals may be considered as comparable entities and the variation between blocks thus gives a measure of the soil gradient error. The sum of squares is obtained therefore from the squares of deviations of the block totals from the mean.
- (d) The random variation—this comprises the variation due to such causes as the smaller soil patches, seeding irregularities, etc., and as it constitutes the remaining source of variation it is obtained simply by subtracting the (b) and (c) components from the total sum of squares.

In obtaining the mean square deviation Fisher made use of a factor which he termed "Degree of Freedom" representing the number of independent comparisons between the plots. The earlier methods of analysis obtained the mean square deviation by the number of plots concerned in each case. Using Fisher's method, the mean square deviation for the component variations is obtained by dividing each of the sums of the squared deviations by the appropriate degree of

freedom. The comparison of these figures for significance was simplified by Fisher, who designed a table based on the logarithmic functions of these values for certain probabilities of occurrence. The table is generally known as the "Z" table.



A cereal variety trial on a wheatbelt research station. Seven wheat varieties were included in this trial of five replications of one-eighth acre plots. The evenness of planting is emphasised in this illustration.

In the randomised block experiment it is possible to test six or seven treatments replicating each block four or five times and, from the results, to eliminate soil variation. The errors obtained from this type of analysis compare favourably with that derived from the Beaven method as they allow for the soil variant factor. The randomised block layout did not find immediate favour with experimentalists, however, as the criticisms were raised that the method presented difficulties not only in seeding and harvesting but also in the analysis of results. The advantages to be derived would appear, however, to far outweigh the disadvantages. While the possibility of mixing seed at seeding and harvesting is, to the plant breeder especially, a reasonably serious disadvantage, a study of the results by the analysis of variance provides him with a means of interpreting them with a high degree of accuracy.

An advantage of the method is that for a given number of varieties or treatments the area required is considerably smaller than for a Beaven trial, thus reducing the possibility of error due to soil variation. It also provides a particularly convenient means of demonstrating fundamental facts to farmers without sacrificing any accuracy in the interpretation of the results. Compared to the Beaven trial it has the distinct advantage that while the accuracy of the experiment is maintained it is still possible to justify the comparison between all varieties.

Analysis of Variance makes possible the inclusion of several factors in the experiment, and the estimation of the proportion of the total variation contributed by each factor, and allows an accurate and valid estimation of the significance of the factor concerned.

It also makes possible the elimination of the variance due to ancillary factors in the calculation of experimental error.

By concentrating on one aspect of a problem only, no consideration is given to the inter-reactions or inter-relations between the variant under consideration and the numerous other variants, which are inevitable in any experimental environment. For instance, when a new cereal variety is put into general cultivation, it must survive the inevitable variations. It becomes highly essential, therefore, that experiments should give some information regarding the inter-reaction between the variable under test and other variables both controllable and otherwise. The value of the Analysis of Variance method in this respect was soon appreciated.

There is a necessity to eliminate the soil variant factor in the Randomised Block layout of experiment. By applying the Analysis of Variance to the results of, for example, a variety trial planted on this design, it is possible to separate the total variance of the experiment into its three components. The method reduces the experimental error by basing its calculations on the error of all the plots, and by the actual elimination in the analysis of that portion of the total variance which can be contributed to differences arising from variation in soil fertility or other factors between blocks as a whole. An important point is that the amount of soil heterogeneity variance removed by block differences depends on the inter-relation of plot size and block size and the type of soil heterogeneity experienced. It is convenient to calculate from the Standard Error and Fishers table of "t" values termed "significant differences" so that in comparing the means of any two varieties these differences in yield would be exceeded by chance only once in 20, 50, or 100 trials which ever is the level of significance chosen.

The Latin Square Arrangement.

In an endeavour to reduce experimental error still further, a modification of the Randomised Block layout was suggested which allowed a further element of control. The plots are planned in a square formation and the varieties or treatments are randomised so that any one variety occurs only once in each row or column. The design allows a consideration of blocks in two directions either horizontally (rows) or vertically (columns). As a result, all varieties are again directly comparable and the design has the added advantage that it permits the elimination of soil heterogeneity between different blocks and also between different columns.

The square formation of the layout limits the application since there must be the same number of replications as there are treatments, thus reducing the experiment to five or six treatments. From the practical point of view the planting of such an experiment would necessitate rather large headlands between blocks. To overcome this difficulty Fisher suggested that if the blocks were situated side by side instead of being placed one behind the other the same type of analysis could be applied. The resultant yields would be tabled in the form of a Latin square and then analysed in this manner.

The analysis of variance of a Latin square experiment is fundamentally the same as that of the randomised block layout. The only modification is that the block sum of squares is virtually duplicated in the rows and in the columns, and the sum of squares attributed to each of these components separately is subtracted from the total sum of squares in estimating the error.

RELATIVE ROLES OF STATISTICIAN AND EXPERIMENTALIST.

The selection of the experimental area, field supervision, collection of data and observation throughout the experiment are all very important if a valid statistical interpretation of the significance of the final data is to be obtained.

Statistical significance is based on the assumption that the estimates of the means and standard deviations obtained from the data are representative of the true values which would have been obtained from an infinitely larger number of plot replicates *i.e.*, from the whole population.

A statistician may recommend a certain experimental design which he considers to be suitable or adequate for the variables to be tested. It should be appreciated, however, that much of the efficiency of any experiment is dependent on the skill of the experimentalist in the selection and sub-division of the experimental area. He must ensure that the plots within blocks are on relatively uniform soil and that the major portion of heterogeneity occurs between blocks to enable it to be eliminated in the calculation of the standard error.

Although the statistician from a study of the yield data may arrive at certain conclusions it is the experimentalist who must give the final interpretation of the results. In this he must exercise great care as he cannot afford to make serious errors in his recommendations. A faulty recommendation could well lead to a loss of confidence in the research work by the very community which the researches are intended to benefit.

Complex Experimentation.

With the development of agriculture in Australia has come the increasing necessity to conduct complex experiments which concern, not one question or problem only, but a series of problems which are directly related to each other. A method of analysing the results from these complex experiments so that a correct interpretation could be obtained has become even more necessary.

The simple type of manurial experiment for example was largely confined either to a comparison of different rates of application of a single fertiliser or to comparison of empirically chosen combinations. With the introduction of the method of analysis of variance, it became obvious that such fertiliser trials could be conducted to advantage in randomised blocks or Latin squares. It was soon appreciated, however, that quantitative comparisons of one fertiliser alone took account of a single component affecting plant development, and disregarded the inter-relation of other fertilisers with the one under consideration.

The randomised block layout proved to be quite suitable to compare, for example, three levels of two fertilisers or two levels of three fertilisers, as the number of plots required was within the limits of practicability. The comparison of say three fertilisers in all combinations, however, would require 27 plots for each replication and the experiment would become unwieldy. In addition, as large numbers of treatments were included, the blocks would become so large that the variance due to soil differences within blocks would increase compared with the variance between blocks, with a proportional increase in the error variance.

The increased difficulty of design and analysis necessary for the complex experiment would suggest that perhaps it might be better if the series of questions to be answered were resolved into a number of simple experiments. The main advantage of the complex experiment, however, is that the number of degrees of freedom associated with the error variance is high, resulting in a more representative estimation of the standard deviation from the data.

A second advantage is that a complex field experiment including several treatment series in all combinations, greatly widens the field of information that would be covered by a number of simple experiments in which each series was tested independently. There is a danger, however, of including a greater number of series of treatments in the one experiment than can be effectively controlled.

In view of the advantage of the complex experiment, it was suggested that the difficulties previously mentioned could be overcome by the use of one or two general methods of what is described as confounding:—

- (1) By the use of the split plot method it is possible to use relatively large plots for one series of treatments and sub-divide these whole plots into a number of sub-plots to superimpose a second series of treatments.
- (2) A second method of confounding has been described by Yates (1933). It consists essentially of confounding not of the treatments but of treatment interactions with block differences.

The split plot design provides a more critical comparison of the sub-plot treatments than it does for the whole plot units. This is due to the larger number of replications of the small units which in turn provide a larger number of degrees of freedom for error. In view of this, Paterson (1939) suggests that the less important treatment effects be allocated to the whole plots and the more important treatment effects to the sub-plots, in order to obtain the maximum precision where it is most desired.

The relative efficiency of randomised block as compared with split plot experiments was studied on uniformity trial data with sugar beets by Le Clerg (1937) both in the field and in the greenhouse. He compared the magnitude of the variance of the sub-plots within main plots in the split plot design, with the variance of sub-plots within blocks in the randomised block arrangement. He concluded that the variance of the sub-plots in the former was markedly less than in the latter, and showed that the split plot design was 71 per

cent. more efficient in one set of uniformity data and 53 per cent. more efficient in another. For comparisons of main plots within blocks there was a decrease in efficiency by the use of the split plot arrangement.

Complex experiments are more efficient than a series of isolated small experiments, and any conclusions induced from the results are usually more reliable since they are based on a wider background. The experimentalist should, however, realise the difficulties which are experienced in most field experiments. While the main aim in the development of statistical techniques has been to overcome experimental error, it would be foolish to utilise a design beyond the scope or requirement of the experiment. In most cases the value of a complex experiment depends upon a careful analysis of the problem, and the various treatment combinations to be tested.

It can be expected that with the increasing complexity of agricultural practice in Australia, will come an increasing complexity in the design of experiments necessary to solve the various problems of reactions and interactions between factors. Whereas primarily field experimentation was applied to the more fundamental problems of agriculture, and simple experimental designs gave satisfactory answers to the problems, the present-day problems are becoming increasingly complex in nature. The determination of the value of various fertilisers at all levels, the effect of various rotations upon crop yields and subsequent soil fertility, are but two examples of the type of questions which require answers and are being answered by the use of complex experiments and the efficient means of analysis of data which are available to the experimentalist.

Application of Statistical Methods to Plant Breeding.

Beaven (1922) wrote "Variety trials of cereals are complex affairs. Moreover the problem has many limitations and is beset by difficulties and sources of error especially in estimates of productivity both in execution and in the interpretation of the results obtained."

Perhaps in no other field of agriculture has the development of efficient experimental techniques and methods of analysis played such an important part as in the field of plant breeding. In the earlier days of plant improvement the breeders had the advantage that the existing varieties were generally of poor quality, with the result that it was often possible to effect quite large improvements. It is to be expected that in the future, any improvements in yielding ability of wheat which can be effected by breeding and selection will be comparatively small and increasingly difficult to detect.

To the plant breeder then, two factors become increasingly important. The first is the need for a thorough knowledge of the heritable plant characters which influence yield. Unfortunately, yield, which represents the end product of growth, is particularly complex and cannot be investigated by the usual methods of genetical analysis. As a result, workers in Australia have generally devoted their efforts to the separate investigation of the various plant characteristics which collectively determine the yielding ability of a variety. Such factors include the tillering capacity, tiller survival rate, grain-straw ratios, number of grains per ear and the average

grain weight etc. A discussion on this subject is beyond the scope of this paper, but it serves to introduce the second important factor in the improvement of yielding ability of varieties—the need of a reliable means of comparing yields on a small scale.



A small scale yield trial with crossbred and introduced flax varieties. The difference in height and maturity can be noted.

Generally the plant breeder is confronted with a number of problems relating to testing for yielding ability. Using a pedigree selection method of breeding, he must select single plants by eye from each generation until the resulting lines can be regarded as sufficiently uniform to bulk them for yield trials. If the Randomised Block yield trials of $1/40$ th acre plots are used, then a large number of lines must be carried through a number of generations to provide sufficient seed for the trial. There is a limit to the number of lines which can be carried, and the number of varieties which can be included in a Randomised Block experiment is also limited.

Although the uniformity of cross-bred lines is usually sufficient for yield testing in the fourth or fifth generation, the seed available at this stage is usually only sufficient for very small plots. Another difficulty about testing cross-breeds at this stage is that the number of selections to be tested is comparatively large. With the Randomised Block layout the error variance which gives a measure of variation within replications tends to increase with increasing numbers of varieties, and so reduces the significance of differences between mean yields. With an increasing number of varieties the precision of comparison may be maintained at the level of significance chosen, by increasing the number of replications. A second and usually more practical method of reducing the error variance with a large number of varieties is provided by the Lattice designs which were first proposed by Yates (1936). This design is particularly useful when shortage of seed or space limits the number of replications. The design and analysis of these trials and their efficiency relative to Randomised Block trials are fully described by Goulden (1937).

There has been a considerable amount of literature written on the subject of the relative efficiency of the two designs. It is apparent that the Lattice designs have not proved less efficient than the Randomised Block design in any trial, while they have given a considerable increase in efficiency in some cases. In view of this, it would seem advisable that in testing a large number of varieties the Lattice design should be used with a field plan that will allow an efficient Randomised Block analysis as an alternative.

Apart from the statistical value of the Lattice designs there are, however, a number of practical applications which have to be considered. The first is that generally plant breeders in Australia do not have an abundance of skilled technicians available, and quite often have to rely on unskilled labour for the planting and harvesting of these small scale trials. The question is raised as to whether the trials with a high degree of statistical precision are warranted when there is the possibility of rather large errors being made in sowing or harvesting. Another objection to their utilisation is that few plant breeding institutions have nursery equipment for sowing and harvesting the plots. This entails considerable manual labour which may quite often be unskilled.

The advantages of the design are, however, too numerous to be ignored, and if the breeder is to be able to detect small but significant differences in yielding ability, then he must use the most efficient experimental techniques and methods of analysis available. Although it is contended that the previous generation of plant breeders did not require lattice squares and statistical methods to produce varieties of outstanding yielding ability such as Bencubbin, it is very likely that present day plant breeders will require these methods to better such varieties.



Portion of a belt planter used for planting lattice square yield trials. The seed is loaded on to two belts and with the forward motion of the machine the seed passes into two distributors and is planted in eight rows approximately one link apart.

Millington (1943) in association with Bateman at the Wongan Hills Research Station conducted an experiment to compare the efficiency of visual selection for yield with selection by means of lattice square trials. Although the results of the experiment were not conclusive they indicated that whereas some lines appeared to be high yielding to the eye this was not supported by the results of the yield trial. Similarly the highest yielding line from the trial appeared to the plant breeder to be not capable of more than an average yield.

It has often been suggested that the use of small nursery plots is of little use as the results obtained from them are not substantiated by larger field plots. Evidence is available, however, to the effect that not only are nursery plot results verified by larger scale experiments, but also by field practice. It is, however, necessary to take adequate precautions against competition and other possible sources of error. Whereas with small plots it is possible to obtain more precise control of soil heterogeneity than is obtainable with larger scale field plots, whether this is balanced in accuracy of results obtained by the sacrifice in plot size is still rather a question of doubt.

It is anticipated that the development of efficient nursery machinery for the planting and harvesting of lattice square and similar yield trials, together with the high degree of statistical precision of such experiments, will be major factors in the production of higher yielding wheat varieties in the future.

CONCLUSION.

Within the last 50 years there has been a great development in the application of statistical technique to wheat agronomy in Australia. It is now generally recognised that a knowledge and appreciation of statistical technique is an essential component of the experimentalist's training, whether he intends to carry out his research in the fields or in the laboratory. Despite this realisation there seems to be within Australia at this time a shortage of experimentalists with a really sound statistical background.

The statistician can only indicate the lines along which an experiment may be designed to enable him to measure certain variables and exclude others. The error which he calculates is simply a measurement of the variation of the yield of the plots. This error is a composite not only of the random patches of soil but also of the irregular seeding, fertilising and harvesting of the plots. An equally important part is played by the field experimentalist in selecting even areas of land for his trial, ascertaining that the seed of his varieties is comparable, and ensuring that the sowing, harvesting and calculation of yields is carried out with reasonable care. "It is therefore essential that where adjustments have to be made between theoretical desirability and practical suitability the latter should have the preference." (Forster and Vasey (1932).)

Many research workers who have not the necessary knowledge of statistical technique are forced to rely in many instances on a mathematician for the design and interpretation of their experiments.

The experimentalist with no appreciation of statistical methods can be extremely dangerous but on the other hand a biometrician with a solid mathematical training but no appreciation of the field problems confronting the experimentalists can be an equal menace.

There seems to be however a particular scarcity of the happy medium—an agriculturist with a full appreciation of statistical technique and a sound training in its application. Often the agricultural graduate who finds himself in the unenviable position of realising his inadequacy in the field of statistics, is faced with two alternatives. Firstly he can return to his mathematics at whatever stage he left them and complete his training in the field of statistics by means of the various advanced courses available. The second alternative is to master the principles of statistical technique without worrying too much about the mathematical proofs of the formulæ he uses. Neither alternative is completely satisfactory and it would appear that the place for the research worker or experimentalist to obtain his sound knowledge of statistical technique is during his undergraduate course at the University.

While it is appreciated that the arrangement of a University curriculum is no simple matter, it is felt that in the future a sound training in experimental technique will be invaluable in almost any career which the graduate chooses to adopt. The necessity for statistical technique in any field of agricultural research can be summed up in the following words:—"I would go further and insist that all biological investigation involves a statistical consideration of the results."—Sir A. D. Hall (Rothamsted Conference, 1931).

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VEGETABLE SEED TREATMENTS

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Many diseases of annual crops and especially vegetables, are caused by parasites which are carried either in or on the seed, or with the seed, in soil or other impurities.

The term "seed" may here be extended to include not only the true seed, but also plant parts used for vegetative propagation such as tubers, bulbs, and root separations, etc. Very occasionally these parasitic organisms may be visible to the naked eye. For example, when potato tubers are affected with the rhizoctonia fungus. Also their presence may sometimes be detected by discoloration of the seed which is often apparent when peas are affected with blackspot or beans with anthracnose.

Generally, however, they are present in the form of bacterial cells or fungal spores loosely attached to the surface of the seed, or as dormant fungal threads within the seed, and because of their microscopic size, the presence of such seed-borne parasites is, in the great majority of cases, entirely unsuspected.

Seed of unknown origin or health should therefore always be regarded with suspicion, for unless precautions are taken, it may give rise to serious diseases, which greatly reduce crop yields.

Various seed treatments are available which minimise this risk, and these can broadly be divided into two main groups, depending on the materials used and the purposes for which they are applied.

(1) *Seed disinfectants* are employed to kill disease-causing fungi and bacteria which are carried on, or in the seed.

(2) *Seed protectants* are applied to protect the seed and young seedlings from moulds or other organisms in the soil which cause pre-emergence damping-off.

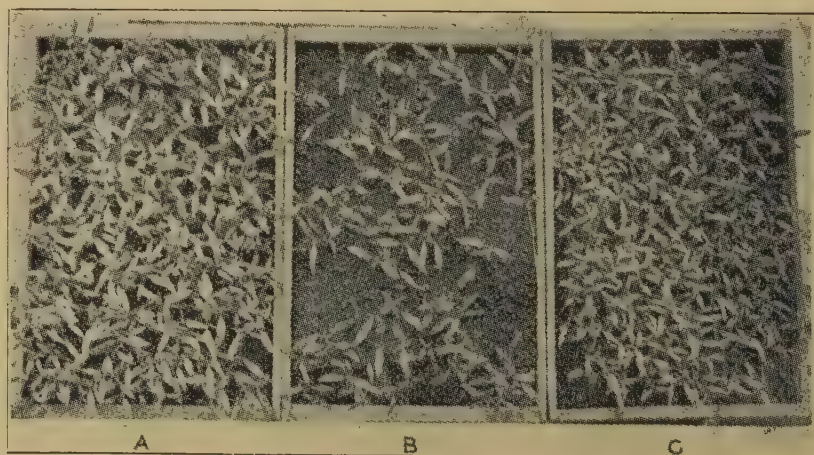


Plate. 1.

Pre-emergence damping-off of tomato seedlings controlled by seed protectant dressings.

- A. Seed dusted with Ceresan. B. Untreated seed.
C. Seed dusted with red cuprous oxide.

[After Chamberlain and Brien. N.Z. D.S.I.R. Plan Dis. Div., Bul. 1.]

Seed carrying parasitic organisms loosely attached to the seed surfaces is disinfected by soaking it in poisonous dips or by coating it with poisonous dusts. Seed disinfectants commonly used to cleanse such contaminated seed consist of corrosive sublimate or formalin solutions, or dusts containing organic mercury, or copper compounds, etc.

In certain cases however, e.g. black leg of cauliflowers and bacterial canker of tomatoes, the causal parasites may penetrate inside the seed, where they are beyond the reach of external poisons. To disinfect such seed, heat is sometimes applied by soaking the infected seeds in hot water. It should be noted however, that hot water seed treatments are only suitable for the control of certain seed borne diseases and should not be used indiscriminately.

Pre-emergence damping off is caused by various decay-producing organisms in the soil which rot the seed, or kill the young seedlings before they emerge above ground. Good control of this trouble may often be obtained by the use of seed protectant dusts, which sterilise the soil around the germinating seeds. As the development of pre-emergence damping-off is unpredictable, seed protectant dressings are a wise insurance and moreover most of the materials used for this purpose are also of value as seed disinfectants.

For example in a local experiment a few years ago it was found that samples of four popular varieties of garden pea—each of which gave more than 90 per cent. germination in the laboratory—gave an average emergence of 8 per cent. only, when planted in soil where pre-emergence damping-off was prevalent. Seed dressed with copper carbonate dust however, gave an emergence of 53 per cent. A new material called tetroc has since proved to be superior to copper carbonate, and is now recommended particularly for dressing pea and bean seeds.



Plate 2.

The value of spinach-seed treatment is well illustrated by comparison of the stand in the nine cuprous-oxide-treated rows on the left with that in the five untreated rows on the right.

[After N.Y. (Cornell), Agr. Exp. Sta., Bul. 566.]

Seed treatments will often prevent the occurrence of diseases in the garden but they should not be relied on solely for this purpose. Rather, they should be used in conjunction with other control measures such as seed-bed disinfection, crop rotation, and general hygiene practices.

VEGETABLE SEED TREATMENTS.

Seed.	Disease.	Treatment.
Bean, French and Runner	Bacterial Blight ; Anthracnose Pre-emergence damping-off	(For smaller quantities of seed than those mentioned, see under methods.) Discard all diseased, discoloured, and shrivelled seed. As for peas.
Beets	Leaf Spot Pre-emergence damping-off	Dip in formalin 2½ oz. to one gallon of water (= 5 tablespoonsful per gallon or 2½ teaspoonsful per pint) for 7 minutes. Rinse in water and plant at once or dry. Dust seed with copper dusts at 2 level teaspoons or organic mercury dusts at ½-1 teaspoon per lb.
Carrot	Pre-emergence damping-off	Dust seed with copper dusts at one level teaspoon or organic mercury dusts at ¼-½ level teaspoon per lb.
Celery	Pre-emergence damping-off Early Blight ; Late Blight	Dust seed with cuprous oxide at 1½ level teaspoons per lb. Dip seed in hot water (118° F.) for 30 minutes. Spread out thinly in shade and dry quickly.
Cabbage, Cauliflower, Brussels Sprouts, Radish, Broccoli and Turnip	Blackleg and Blackrot Blackrot Pre-emergence damping-off	Immerse seed in hot water (122° F.) 25 minutes for cabbage and 15 minutes for others. Spread thinly in shade and dry quickly. Immerse seed in corrosive sublimate 1-1000 strength, 30 minutes for cabbage and 20 minutes for others. Drain and then rinse for 15 minutes in clean running water. Spread to dry in shade. Prepare solution by dissolving ¼ oz. of corrosive sublimate in 1 gallon 4½ pints of water or by dissolving prepared tablets in water as recommended on the container. Dust seed with zinc oxide at 2 level teaspoons per lb. or organic mercury dusts at ¼ level teaspoon per lb. <i>Copper dusts are not recommended as they may cause injury.</i>
Cucumber, melons, marrow and pumpkin	Pre-emergence damping-off Fusarium Wilt	As for carrot. Immerse seed in mercuric chloride (1-1000) for 5 to 7 minutes. Wash 15 minutes in clean running water and spread thinly to dry in shade.

VEGETABLE SEED TREATMENTS—*continued.*

Seed.	Disease.	Treatment.
Lettuce	Pre-emergence damping-off	Dust seed with zinc oxide at 2 level teaspoons per lb.
Onion	Pre-emergence damping-off	As for lettuce.
	Red root	Immerse seed in mercuric chloride (1-1000) for 30 minutes. Wash for 15 minutes and spread thinly to dry in shade.
	Downy Mildew	Immerse seed in hot water (122° F.) for 25 minutes. Spread thinly in shade and dry quickly.
Peas	Pre-emergence damping-off	Dust seed with tetroc at rate of 1½ ozs. per bushel (= ½ level teaspoon per lb.). N.B.—If seed is to be inoculated, apply bacterial culture to the <i>dusted</i> seed just before planting.
	Foot Rot and Root Rot	Discard seed which shows brown or black marks or is badly shrivelled.
Potatoes	Rhizoctonia, Common Scab	Dip seed, unsprouted and uncut, for 10 minutes in acidulated mercuric chloride (4 ozs. dissolved in 1 quart of commercial hydrochloric acid) added to 25 gallons water. After 10 dippings, extend time to 15 minutes for each of 5 additional dippings, then discard solution. <i>Plant at once or dry thoroughly and store ; or</i> Dip in proprietary organic mercury dips according to directions on container.
Rhubarb (roots)	Foot Rot and Crown Rot	Soak roots in mercuric chloride (1-1000) for ½ hour. Wash and spread out to dry.
Spinach	Pre-emergence damping-off	As for beet.
Tomato	Various diseases	Immerse seed in hot water (122° F.) plus 0.25% commercial formalin (1 fluid oz. or 2 tablespoonsful formalin in 2½ gallons of water) for 25 minutes. Spread thinly in shade and dry quickly. Dust seed with organic mercury dusts at ¼-½ level teaspoon per lb. before planting

METHOD AND MATERIALS.

Dusts are applied by placing seed and dust in a Mason jar or other tightly lidded container, and shaking vigorously for several minutes, until the seeds are evenly coated. Any excess dust should be screened off.

For small amounts of seed, for example, a 6d. packet, it is impossible to recommend a definite measure of dust owing to the variable quantity of seed contained.

In such cases, a pinch of dust may be shaken up with the packeted seeds until they are thoroughly coated, and the excess dust screened off.

Hot Water Seed Treatments must be carried out carefully for the temperature required to kill a seed-borne pathogen is generally not much below that at which seed injury occurs. The duration of treatment is also important, for if prolonged beyond the recommended period liability to injury is increased. To ensure uniform temperature conditions during the steep, a large volume of water in proportion to seed should be used, e.g., $\frac{1}{4}$ to $\frac{1}{2}$ -lb. per 3 gallons.

Hot water seed treatments may be carried out simply and effectively with the following equipment and procedure. Fit a kerosene tin with a wooden lid in which two half inch diameter holes have been bored. Place the tin in a box and insulate it underneath and around the sides with a packing of straw, chaff, bran, etc.

Pour boiling water into the tin until it is about three quarters full and leave until the temperature drops to about 1 degree above the required seed treatment temperature.

Then tie the seed loosely in a cheese cloth or muslin bag and suspend it in the hot water with a string passed through a hole in the lid. Through the other hole an accurate thermometer is inserted. Adjust the temperature as required with boiling or cold water which should be ready to hand and stir the water frequently by raising and lowering the bag of seed.

On completion of the steep, withdraw the bag of seed and roll it gently in a towel to remove as much water as possible. Then spread the seed out thinly on paper in the shade, and stir it to promote rapid drying. If desired the seed may be planted as soon as it is dry enough to separate freely, but if it is to be stored it should be thoroughly dried for a further two days before being packed in a clean container.

The germination of good quality seed is not impaired by hot water treatment.

Corrosive sublimate (mercuric chloride) is a *deadly poison* and it also corrodes metals. It should therefore be kept well out of reach of children and animals, and solutions should be prepared in glass, enamel, or earthenware vessels, etc.

Corrosive sublimate may be purchased in powder or tablet form from wholesale or retail chemists.

To prepare a 1:1,000 solution, 1 tablet is dissolved in 1 pint of water, or 1 ounce of the powder dissolved in $6\frac{1}{4}$ gallons of water. As the chemical is only slowly soluble in cold water, it should be dissolved in a little hot water, and water added to make the final volume.

Small quantities of solution are most conveniently prepared with tablets, but when larger quantities are required, the powder form of corrosive sublimate is cheaper.

In the latter case the most convenient method is to prepare a stock solution containing 2 ounces of the corrosive sublimate powder in 1 gallon of water, and to dilute portions of this for use as shown in the table on page 6.

DILUTION TABLE FOR MAKING 1 IN 1,000 CORROSIVE
SUBLIMATE, USING A STOCK SOLUTION OF TWO OUNCES
IN ONE GALLON.

Stock Solution. Take amount indicated below.	Dilute with clean cold water in wooden, glass, cement, or earthenware container to final volume indicated below.
(a) $\frac{1}{4}$ pint	$3\frac{1}{4}$ pints
(b) $\frac{1}{2}$ pint	$6\frac{1}{2}$ pints
(c) $\frac{3}{4}$ pint	1 gallon $1\frac{3}{4}$ pints
(d) 1 pint	1 gallon $4\frac{1}{2}$ pints
(e) $1\frac{1}{2}$ pints	2 gallons $2\frac{3}{4}$ pints
(f) 1 quart	3 gallons 1 pint
(g) $\frac{1}{2}$ gallon	6 gallons 2 pints
(h) 1 gallon	$12\frac{1}{2}$ gallons

Formalin.—Commercial formalin (40 per cent. formaldehyde solution) has a pungent odour and it is irritating to the eyes. It does not attack metals.

It is useful not only for disinfecting seed against certain diseases but also for sterilising soil, tools, stakes, boxes etc.

Tetroc (spergon) is a new seed protectant which gives outstanding control of pre-emergence damping-off of peas and beans. It is obtainable from leading seedsmen.

Organic mercuric dusts are sold under various proprietary names including "Agrosan" and "Ceresan." Both are stocked by seedsmen.

Organic Mercury dips, e.g. "Aretan" and "Hortosan" have been developed for the quick disinfection of tubers and bulbs. They are convenient for the home gardener, but they are probably not so effective as the longer corrosive sublimate dips. These materials are stocked by seedsmen.

Zinc oxide is a relatively mild seed dressing. It may be purchased from any chemist but as finely divided a form as possible should be used.

Copper Dusts—

Copper carbonate is widely used in this State for dry pickling wheat against bunt or stinking smut. It is stocked by practically all firms with agricultural interests, by large stores, and by seedsmen.

Copper oxychlorides are sold commercially under such proprietary names as "Smutol," "Cuprox," and "Soltosan."

"Smutol" has been mainly used in the past for dressing seed wheat, and "Cuprox" and "Soltosan" as Bordeaux-mixture substitute sprays. All three substances may be used, however, for dressing various vegetable seeds.

Cuprous oxide. Seed treated with this substance, unless planted immediately, should be kept in an airtight container to avoid spoilage through oxidation.

Precautions.

Most of the materials mentioned are poisonous in varying degrees, therefore the usual precautions should be observed when storing or applying them.

NEW CEREAL VARIETIES IN AUSTRALIA.

I. THOMAS, Registrar of Cereal Varieties in Australia.

IN 1927, a conference of the State Ministers for Agriculture at Adelaide resolved that to avoid duplication, the names of new cereal varieties be circulated among the States and subsequently confirmed at a meeting of Ministers. Later the Standing Committee on Agriculture decided to further discourage the indiscriminate release of varieties and in 1937 the following resolution was carried:—

That each State proposing to introduce a new cereal variety should advise the other States giving full characteristics including yield, milling value and baking qualities and also stating the variety or varieties it is proposed to replace.

This cereal registration system although purely voluntary has achieved its principal objectives of preventing duplication of names and the indiscriminate release of varieties. It has served also to keep breeders advised as to new releases.

The procedure in brief is that an organisation wishing to release a new variety for general cultivation submits particulars of its morphology, disease resistance and yielding capacity, together with the proposed name and pedigree to the registrar. The information is then forwarded to the organisations engaged in cereal breeding to ascertain whether they have any objections to the proposed registration. In the absence of objections the variety is accepted and the Agricultural Council advised.

During 1950 two new wheat varieties namely Lawrence and Macquarie were registered. The variety Lawrence was submitted for registration by the Queensland Department of Agriculture and Stock, while the variety Macquarie was produced by the Tasmanian Department of Agriculture. The particulars of the new varieties as supplied to the Registrar are as follows:—

Lawrence.

The cross Florence x College was originally made by Mr. R. E. Soutter at Kincora in 1932. College was an unknown variety which was utilised for its rust resistance and has since been almost definitely identified as the variety Hope.

Lawrence is late maturing being approximately equal to Ford in this respect and is tall growing with fine white straw.

The early growth is spreading and weak, but the amount of tillering is good.

The head is white, tapering, smooth and possesses small, persistent tip awns. The grain is held well, there being no evidence of shedding. The grain is white, round, and semi translucent and is regarded as being of good milling quality.

The variety is resistant to all forms of stem rust and leaf rust prevalent in Queensland which indicates resistance to races 126 and 126B in addition to a new complex of races recently identified in New South Wales.

A general outline of the capabilities of this wheat, is given in the following extract from the form of registration submitted by the Queensland Department of Agriculture and Stock.

"The variety is capable of useful yields under reasonably good conditions in Queensland, and is recommended as a substitute for Ford and Warput in early sowings. Its high resistance to stem and leaf rusts, its better palatability and cold resistance than most Queensland varieties, makes it a useful dual purpose wheat. The variety has good loaf volume, enabling it to support weaker flours in a blend, and may have a higher moisture content requirement than most of the quick maturing varieties forming the main crop Queensland sowing."

Macquarie.

This variety resulted from a cross between Sutton and Braemar Velvet, made by A. H. Woodforde at Launceston in 1932 and selected at the Cressy Research Farm, Cressy, Tasmania. Macquarie is a tall growing wheat with fine, white straw of fair strength. Of late maturity, it possesses ears which are white, smooth and tapering with a persistent tip awn, whilst the grain is white and starchy, and of low flour quality. Disease resistance is lacking, the variety being susceptible to bunt, smut and both stem and leaf rusts. The Tasmanian Department advises that Macquarie has been bred specifically as a biscuit variety, and in this respect Extensograph, Farinograph and test bakes have indicated that the variety has the properties of being a superior biscuit wheat.

The yielding ability of the variety compares favourably with Major, one of Tasmania's primary wheats.

THE CONTROL OF INTESTINAL ROUND WORMS IN POULTRY.

R. H. MORRIS, Agricultural Adviser.

CONSIDERABLE economic loss is experienced each year by those engaged in the Western Australian Poultry Industry, through the ravages of large round worms (*Ascaridia galli*) in their birds. It is in young stock, i.e. poultry three to nine months of age that round worms cause greatest havoc. The adult worms are found in the intestines and the damage caused is the result of two things.

In the first place the worms manufacture toxins that are absorbed into the bird's system and, secondly, the burrowing of the worms into the intestinal wall results in it becoming so scarred and thickened that the food nutrients have difficulty in passing through it into the blood stream. The bird is therefore unable to make the best use of its food.

When birds are only slightly worm infested, only mild symptoms are shown and these may not arouse suspicion. When, however, a heavy infestation occurs, very marked symptoms will be noticed. The birds develop a thirst, lose their appetite and therefore lose condition. Growing pullets that are worm infested develop slowly, and, instead of coming into production at from five to six months, they are very often nine months old before they lay their first egg. The feathers become ruffled (i.e. they do not lie close to the body) and



This photograph is typical of a heavily worm infested pullet. Once a bird becomes as sick as this she is unlikely to ever become profitable. The secret is successfully combating worms is to free the birds from worms before any damage is done. Two routine deworming treatments should, therefore, be an integral part of every rearing programme; these treatments to be carried out when the young stock are 10 and 18 weeks old respectively.

(By courtesy T. G. Hungerford, "Diseases of Poultry in New South Wales.")

frothy, mustard coloured droppings are passed. The comb, head region and shanks become very pale and the face and eyes sunken. In extreme cases the birds lose the use of their legs, but normally, infested fowls remain sickly and emaciated for a long period unless treated.

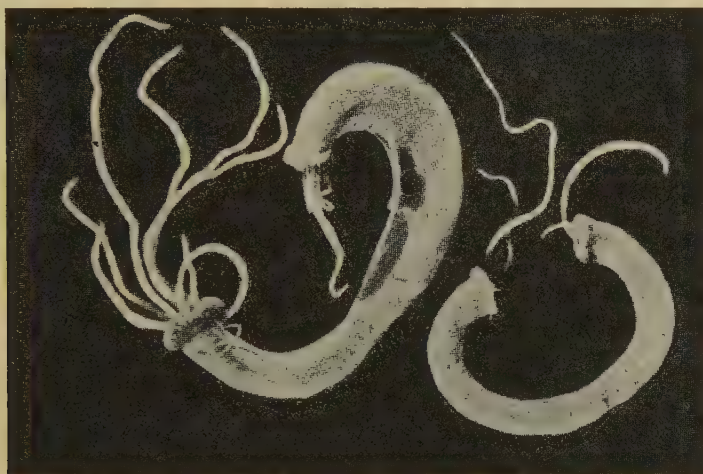
Where worm infestation is suspected it will pay to kill and examine a bird. The intestines should be slit open with a pair of scissors. The presence of the worms will then easily be seen.

Life Cycle.

An appreciation of the life cycle of the parasite is important as one of the control measures, namely sanitation, is based on interrupting its life cycle.

The life cycle of the parasite is direct. The mature female worm in the intestine lays eggs and these are passed in the droppings. Under suitable conditions of warmth and moisture the eggs develop into infective bodies. Suitable moisture conditions are provided in fowl runs by dripping taps and overflowing drinking vessels. Damp, shady

spots should be eliminated. Suitable temperatures are provided by normal atmospheric temperatures that prevail during the spring and summer months. The infective bodies may develop within eight days of the eggs being laid. If this form of the parasite is swallowed by a fowl, a young worm hatches from the egg and burrows into the intestinal wall causing damage to the digestive glands, for a period extending from about the 10th to the 20th day after the egg is swallowed. The worm then returns to the interior, or lumen of the intestine and develops into an adult in about two months.



Two sections of a small intestine, showing round worms protruding from each end.

(By courtesy T. G. Hungerford, "Diseases of Poultry in New South Wales.")

Prevention.

Worm eggs can carry over in the ground for long periods. Because of this and for many other reasons chickens should be reared on clean ground, preferably on that which has never carried other poultry, or at least on ground that has been rested for six months and which has been well limed and planted to crop.

The removal of droppings from beneath the perches at day break during the deworming period is important in preventing re-infestation.

Control.

Successful farmers realise that a heavy worm infestation is necessary before the birds show obvious signs of being affected. They also realise that some time elapses from the time the birds first become infested until the worm numbers build up sufficiently to constitute a heavy infestation. For these reasons, these men make it a practice to de-worm their growing stock when their birds reach certain ages irrespective of whether they show signs of worm infestation or not. By doing this, the birds derive maximum benefit as they are freed from worms before the worms have sufficient time to become established in large numbers and thereby cause damage, which in many cases, is irreparable.

Of the several vermifuges or worm expellents that have been experimented with, three have been shown to be superior. These are Nicotine Sulphate, commonly known as Black Leaf 40, Carbon Tetrachloride and Tetrachlorethylene.

Where only slight infestation is suspected, flock dosing with Black Leaf 40 through the medium of a wet mash is recommended. Where the worms have been allowed to become firmly established with consequent loss of the birds' appetite, individual dosing with carbon tetrachloride is advised. Another very effective and most convenient method of de-worming, especially where no more than 100 or 200 birds have to be treated, is to use gelatine capsules which contain the drug tetrachlorethylene.

Two brands of these capsules are on the Western Australian market. These are known as "Bio" worm capsules and "Nema" worm capsules respectively, and are sold in cartons containing 50 capsules priced at approximately 7s. per 50 doses (dose 1 c.c.). These capsules are obtainable from a number of different firms in Perth who stock poultry medicines. The capsules contain varying amounts of tetrachlorethylene depending on the size and age of the birds to be treated.



Adult Round Worms (*Ascaridia galli*) measure approximately three inches in length, are cream in colour and a menace to the poultry industry.

(By courtesy T. G. Hungerford, "Diseases of Poultry in New South Wales.")

The following dose rates of tetrachlorethylene are recommended:—

Chickens up to eight weeks, $\frac{1}{2}$ c.c. per bird.

Chickens over eight weeks, 1 c.c. per bird.

Adult birds, 2 c.c. per bird.

Turkeys, 1, 2, 3 c.c. according to size.

Two de-worming treatments should be given growing stock, and these treatments will be most effective if given when the birds are 10 to 18 weeks old respectively. The capsule is easily placed down the bird's throat while the bird is on the perch at night. The droppings should then be collected at daybreak the following morning.

It is all important to see that the pullets are free from worms when they commence production. Worm infested laying pullets will not produce many eggs and must therefore be de-wormed. However a belated de-worming treatment such as this is very likely to force laying pullets out of production and into a moult which could last for several weeks and result in large financial loss. Hence the importance of seeing that the pullets are free from worms when they commence production.

Black Leaf 40 is the easiest and most satisfactory drug to use when the young stock are only slightly affected with worms, i.e., when the birds do not even show signs of being affected. The birds should not be carrying many worms when they come into production if they are treated at 10 and 18 weeks of age respectively, with Black Leaf 40.

The following de-worming programme is recommended:—

First Treatment when Chickens are 10 Weeks of Age.

Three quarters of a tablespoonful of Black Leaf 40 in the water which is used to mix the wet mash to each 250 chickens for six consecutive days.

Second Treatment when Chickens are 18 Weeks of Age.

One tablespoonful of Black Leaf 40 in the water which is used to mix the wet mash to each 250 chickens for six consecutive days.

Providing the pullets are de-wormed when they are 10 and 18 weeks of age respectively they should not require further de-worming during their first year of lay. For chickens hatched in season (June-August) this would mean the following May twelve months when the hens have completed their first year of lay and are moulting. The dose rate of Black Leaf 40 and the method of dosing hens is the same as for chickens 18 weeks of age.

The all dry mash system of feeding is advocated by this Department and many farmers who feed nothing else but dry mash are more than pleased with the results they are getting from this method of feeding. Now that mill offal is more available it is reasonable to suppose that all dry mash feeding will become even more popular.

The fact that birds might be fed dry mash only, does not preclude the use of Black Leaf 40 as a de-worming agent. It does, however, entail the mixing of a wet mash for a few days. A successful procedure followed by many farmers who normally feed dry mash only, is as follows:—

Each time the birds are de-wormed (normally twice in the growing period) the birds are given wet mash on eight consecutive days. To get the birds used to a wet mash it is fed without Black Leaf 40 for the first two days and for the six remaining days the medicated mash is given as outlined above. Normally no difficulty should be experienced in getting the birds to eat this wet mash but the inclusion of chaffed succulent greens in the mash will improve its palatability. It is also important to see that the birds are given as much wet mash as they can eat at each feeding, as by spreading the required quantity of Black Leaf 40 over a large amount of food, the mash will not be made unpalatable.

table by too high a concentration of Black Leaf 40. Within twenty minutes of giving it to the birds the wet mash should all be eaten. When dry mash is fed, the dry mash hoppers should be closed down at midday and the wet mash given as late in the day as possible.

Epsom salts are unnecessary following the administering of worm expellents but it is sound practice to starve the birds for 12-24 hours prior to treatment. The starvation period being dependent on the method of dosing and the time of day at which the treatment is carried out.

The birds can receive food an hour after dosing and if this is possible a 22-24 hour starvation period is advised. If, however, the birds are treated early in the evening, while on the perch, as is sometimes done when capsules are used, a 12 hour starvation period is more satisfactory. In this case it will be the following morning before the birds have an opportunity of eating.

Where Black Leaf 40 is used the birds should be starved for 24 hours immediately prior to the first day's treatment only. Where carbon tetrachloride is used, the birds should be starved for approximately 22 hours and then given the drug with the aid of a carbon tetrachloride gun, the nozzle of which should extend down into the crop. It is very important to see that the nozzle enters the gullet or passage to the crop and not the windpipe, as even a drop of carbon tetrachloride on the lungs will cause instant death.

If the carbon tetrachloride is administered late in the afternoon it will enable the birds to feed before going to roost.

The following dose rates, using carbon tetrachloride are recommended:—

For chickens 10 and 14 weeks old, $1\frac{1}{2}$ c.c. per bird.

For chickens more than 14 weeks old, 2 c.c. per bird.

~~Light breed fowls, 2 c.c. per bird.~~

Hens 3 c.c. per bird.

~~Heavy breed fowls, 2 c.c. per bird.~~

At present prices the cost of treating 1,000 hens with either carbon tetrachloride at the dose rate of 3 c.c. per bird or Black Leaf 40 at the rate of one tablespoonful to every 250 adult birds for six consecutive days is 15s. Birds should be treated for worms late in the afternoon as most of the worms and their eggs are voided within six hours of dosing. If the treatment is carried out late in the day, it means that the worms and their eggs are voided while the birds are on the perches. The droppings should then be collected at daybreak the following morning before the birds have an opportunity of scratching the droppings, so spreading the worm eggs over the farm, and becoming re-infested.

Another important treatment which all growing stock in Western Australia should receive is that of vaccination against chicken pox. Chickens that are to be vaccinated for chicken pox should be in the best of health and above all, should be free from worms or heavy mortality may result. With this in view the following programme is recommended.

De-worm at 10 weeks.

Vaccinate against fowl pox at 12 weeks.

De-worm at 18 weeks.

Birds from a number of different farms in Western Australia have

been shown to have suffered from infectious laryngo tracheitis and where vaccination against this disease is practised the following programme is recommended.

De-worm at nine weeks.

Vaccinate against infectious laryngo tracheitis at 11 weeks.

Vaccinate against fowl pox at 13 weeks.

De-worm at 18 weeks.

In conclusion the relationship between round worms, Vitamin "A" and protein should be mentioned.

Birds suffering from a Vitamin "A" or protein deficiency are very susceptible to worm infestation and conversely a heavy worm infestation will prevent birds from fully utilising the Vitamin "A" and protein that is supplied to them.

Too many birds suffer from a Vitamin "A" deficiency in Western Australia, and many birds submitted for post mortem examination to this Department, are shown to be suffering from both a heavy worm infestation and a Vitamin "A" deficiency.

WHEAT VARIETY TRIALS ON RESEARCH STATIONS—1950.

I. THOMAS, Superintendent Wheat Farming, and
E. R. WATSON, Geneticist and Cereal Research Officer.

The methods of comparison between different cereal varieties in the earlier days of agriculture in Australia were very arbitrary in the light of present day knowledge. At times the yields per acre of different varieties being compared were computed from very large plots in the same paddock. These were not necessarily adjacent plots, and more often the comparisons were based on yields per acre from plots in different paddocks, or even on different farms. Very little thought was given to the differences due to variations in soil and climatic conditions.

It is to the credit of Dr. G. L. Sutton that he placed field experimentation in Australia on a definite scientific basis. He commenced his experimental work at Cowra Experiment Farm in 1902, with what must be regarded as the first record in Australia of organised field experimentation. His later work at Cowra provided him with a background which proved invaluable when he took up his position of Commissioner for the Wheatbelt in this State in 1911.

Sutton was responsible for the development of the three plot system of field experimentation which was used on the research stations in this State for many years. The system has now been largely replaced by the randomized block design but the three-plot layout is still undisputed as the ideal method from the point of view of demonstration of fundamental facts to the farming community.

The randomized block layout has now been adopted for most cereal trials on the wheatbelt research stations for a number of reasons. Firstly, the design is still valuable as a means of demonstration to farmers, and secondly, the plots can be sown and harvested with normal farm equipment. The third, and perhaps most important reason, is that the design allows of the results being statistically analysed.

Such an analysis ensures that the differences between varieties are due to the varieties alone, and not to such variable factors as the soil and climate, etc. With the randomized block layout, each variety is sown once in each of five blocks, the position of the particular variety in each block being selected at random. The use of five replications increases the possibility of obtaining accurate data from the experiment.

Due to such uncontrollable factors-as soil variability, two adjacent plots sown on the one day to the same variety, and with identical cultural treatments, may not give equal yields. By the use of a proper experimental design it is possible to calculate in bushels per acre, the allowance which must be made for the uncontrollable factors. This is calculated in terms of bushels per acre and percentage, and is designated "difference for significance $P=.05$." Any differences, greater or less than these figures, can be regarded as being due to the varieties alone, and not due to the uncontrollable factors.

SMALL SCALE YIELD TRIALS.

The large number of crossbred varieties which must be tested for yielding ability necessitated a different type of experimental technique. Quite often there are hundreds of crossbreds, of which only limited quantities of seed are available, which must be evaluated for the most important aspect of yielding capacity. In addition to the limiting factor of the amount of seed available (usually only a few ounces), the randomized block layout for such a large number of varieties, would become very cumbersome.

To overcome these disadvantages, small scale yield trials have been designed. These are usually termed "lattice square trials" because of the lattice like manner in which the plot distribution is designed. The layout of these trials is such that statistical analysis of the results can detect the small differences, which can be considered as being of value or of being significant.



A portion of the wheat crossbreeding section of the plant breeding rows at Merredin Research Station. Each half chain row in this section is sown with seed of a promising plant, selected the previous season.

Just as Dr. Sutton laid the foundations for a practical, and yet scientific system of field experimentation in this State, he also originated and adapted methods of plant breeding which are still in use, and which have been largely responsible for the valuable results achieved by Western Australian plant breeders. His major contribution in this respect, was that plant breeding should be conducted along definite planned lines with standardised procedures which would enable results to be compared at different research stations, and from one season to another.

Although yielding ability is considered to be very desirable there are other aspects which are equally important and the plant breeder should not be tempted to sacrifice one aspect at the expense of another. Two most essential considerations with wheat breeding in this State, are the factors of disease resistance and flour quality. It is not considered that a variety has a good yielding capacity unless it is capable of yielding well under conditions of disease epidemics, as well as under more normal conditions. Likewise it is not sufficient that a variety be capable of high yields, but it must give high yields of high quality grain. These two aspects of wheat breeding are briefly discussed below.

DISEASE RESISTANCE.

Flag Smut.

The pioneer work on the inheritance of flag smut resistance in the variety Nabawa, was initiated by the late E. J. Limbourn at the Merredin Research Station in 1923. Since that time breeding for resistance to this disease has been given an important place, and the aim of this Department is not to release any variety unless it is immune or highly resistant. Due to the Australia-wide popularity of Nabawa and later Bencubbin and other flag smut resistant varieties, the disease which once caused reasonably high annual losses throughout Australia, is no longer regarded as being of great concern.



A portion of the Flag Smut Trial. Crossbreds and new introductions are artificially inoculated with flag smut spores to determine their resistance to the disease.

Farmers should not forget, however, that flag smut can only be effectively controlled by the use of resistant varieties. Any other control measures are tedious and usually unsatisfactory. It is regrettable that the variety Gabo, which is suitable in most respects, is fairly susceptible to this disease. It can be expected, that if large areas are sown to a variety which is susceptible to flag smut, it will only be a matter of time before field epidemics of the disease are again experienced.

Stem Rust.

Unlike flag smut which is apparently a fairly stable type of disease, stem rust presents more serious difficulties to the plant breeders. Stem rust is composed of numerous physiological races, which differ in the varieties which they are capable of attacking. Breeding for resistance to these races is in effect, the same as breeding for resistance to different diseases.

The position regarding the more important rust races in Australia has been summarised in a previous issue of this Journal (Thomas and Watson, 1950). It is sufficient to repeat here, that whereas no further incidences of the Eureka and Wongoondy attacking race (race 126B) have been confirmed, it is fairly definite that this race is now present in this State. It is possible, therefore, that in the event of an epidemic in Western Australia, this race will be the dominant race present. This has been the experience in other States where race 126B has been isolated. In the event of this occurring, the varieties Eureka, Frisco and Wongoondy would be liable to attack.

A further race, or complex of races, was isolated in New South Wales in 1948. The varieties such as Yalta, Charter, Kendee and Gabo, which were resistant to race 126B, proved to be susceptible to this new race complex. The Western Australian variety—Dowerin, is still resistant to these new races and although it is not generally as prolific as the standard varieties, supplies of seed would be a good form of insurance in the event of a "rusty" season being predicted.

It is to be hoped, however, that this State will enjoy a period of immunity from this new complex of races such as was experienced with race 126B. There is, however, no guarantee that this will be the case, and new crossbreds with the Dowerin (or Kenya C6041) type of resistance are now undergoing preliminary yield trials.

It is sometimes argued that the time spent on breeding for resistance to stem rust could be better devoted to breeding for yielding ability. This argument is based on the history of only four serious epidemics of stem rust in this State since 1915 (i.e. 1915, 1917, 1934 and 1943). There is, however, always a danger of further epidemic years. If it is possible to breed varieties of wheat which have the same or better yielding ability than the popular varieties and at the same time possess resistance to stem rust, then these resistant varieties will be extremely valuable should an epidemic occur at any time.

FLOUR STRENGTH.

It is to the credit of plant breeders in Australia that they have succeeded in producing a number of varieties of high yielding ability which also possess disease resistance and produce flour of high baking quality. The disease resistance and baking quality of these varieties are summarised in Table No. 1, while the yielding ability of those varieties which have been included in yield trials on the wheatbelt research stations, is summarised in Table No. 3.

TABLE 1.

Variety .	Produced by.	Maturity.	Flag Smut Resistance.	Grain Quality.	Stem Rust Resistance.
Eureka	N.S.W. D. of A.	Midseason	Moderately resistant	Approaching premium quality	Susceptible in Eastern States. Thought to be susceptible in W.A.
Frisco	N.S.W. D. of A.	Early midseason	Resistant	Medium strong flour class	Susceptible in Eastern States. Thought to be susceptible in W.A.
Wongoondy	W.A. D. of A.	Early	Highly Resistant	Approaching premium quality	Susceptible in Eastern States. Thought to be susceptible in W.A.
Gabo	Sydney University	Early	Fairly susceptible	Approaching premium quality	Susceptible in Eastern States. Resistant in W.A.
Kendee	Sydney University	Early midseason	Resistant	Medium strong flour class	Susceptible in Eastern States. Resistant in W.A.
Charter	N.S.W. D. of A.	Early midseason	Highly Resistant	Premium class	Susceptible in Eastern States. Resistant in W.A.
Yalta	N.S.W. D. of A.	Midseason	Highly Resistant	Premium class	Susceptible in Eastern States. Resistant in W.A.
Dowerin	W.A. D. of A.	Early midseason	Resistant	Above f.a.q. quality medium strong	Resistant in all States.

The point is again stressed that it is not sufficient to grow a variety of inherently high flour quality to insure producing a yield of good quality grain. Varieties can only express their inherent quality to the fullest when grown under suitable climatic and soil conditions. The farmer cannot influence the climatic conditions, but he can influence his soil fertility. The growing of suitable legumes will improve the fertility of the lighter soil types and help maintain the fertility of the heavier lands.

The farmer may contend that he is not interested in flour quality as it does not affect him, but by growing the varieties which will assist in the raising of the level of the State f.a.q., he will indirectly influence the price obtained per bushel.

SEASONAL CONDITIONS AT RESEARCH STATIONS, 1950.

It is fortunate that the location of the five wheatbelt research stations is such that the results obtained from trials on these stations present a reasonably overall picture for the wheatbelt. It is not possible to conduct trials in each district in the wheatbelt, but by studying the results from the different research stations, the farmer is able, by comparison with his own soil and climate conditions, to translate the results for himself.

The monthly rainfall figures for each of the five stations are summarised in Table No. 2.

TABLE 2.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	Nov.	Dec.	Annual Total.
Growing Period Rainfall.															
Avondale Average	1950 24 years	78	...	...	...	325	265	240	88	138	78	1,134	41	15	1,268
		24	33	92	74	213	327	302	233	106	78	1,259	56	29	1,567
Chapman Average	1950 45 years	...	2	...	...	487	245	371	252	131	84	1,570	58	5	1,635
		25	37	64	74	232	414	390	263	145	88	1,532	40	25	1,797
Merredin Average	1950 40 years	19	...	...	...	284	91	146	102	114	77	814	14	...	847
		40	50	88	84	136	188	182	152	80	73	812	41	53	1,166
Salmon Gums Average	1950 25 years	61	8	...	...	392	69	144	105	99	116	925	52	15	1,063
		76	81	129	86	131	144	146	148	93	115	776	91	75	1,314
Wongan Hills Average	1950 25 years	...	2	25	...	252	158	224	131	96	94	955	35	3	1,020
		32	43	91	90	183	262	263	205	91	71	1,075	46	37	1,414

It will be noted that although the annual recordings are considerably below average for all stations, those for the growing period were approaching, and in some instances, better than average. In contrast to the two previous years, the rainfall for May throughout the wheat-belt in general was well above average. August was the critical month, but with timely rains towards the end of that month, followed by beneficial falls in September and early October, the finishing period was good, and crops generally matured under favourable conditions.

Avondale.

The good rainfall experienced in May enabled planting to be carried out under favourable conditions. Though the August rains were very much below average, crop growth was good throughout the season, and is reflected in the yields obtained.

Chapman.

With the early opening of the season it was possible for the cropping to be carried out under favourable conditions. Conditions throughout the whole of the growing season were ideal, particularly as the excellent falls received in September were followed by further good finishing rains early in October.

Merredin.

At this station very satisfactory opening rains were experienced during May, which enabled cropping operations to be commenced and carried out under good conditions. There were, however, rather light recordings in June and again in the early part of August when the crops deteriorated considerably. Excellent falls were recorded in the latter part of the month, however, and the crops, though short, made a good recovery. With further beneficial rains during September and early October, the crops matured reasonably well.

Salmon Gums.

Cropping operations were carried out under rather difficult conditions. Copious rains fell during May causing some of the experimental area to become water-logged. This prevented satisfactory weed control, and as a result weed growth over a portion of the area was a serious competitor to the crop. The subsequent growing conditions were reasonably satisfactory, with beneficial recordings during the finishing period.

Wongan Hills.

Cropping was carried out at this station under good conditions due to the reasonably early opening rains in May. Conditions throughout the growing period were fairly satisfactory, and with the good finishing conditions experienced, the crops matured well with high yields.

RESULTS OF THE 1950 WHEAT VARIETY TRIALS.

The results of the 1950 trials are tabulated in Table No. 3. The rather low yields from the trials at Salmon Gums were due to the very weedy conditions of the area on which the trials were sown. This was caused by unfavourable conditions experienced at planting time, as discussed previously.

TABLE 3.
WHEAT VARIETY TRIALS AT RESEARCH STATIONS, 1950-51 SEASON.

	AVONDALE.			CHAPMAN.			MERREDIN.			SALMON GUMS.			WONGAN HILLS.		
	Percentage of Control.		Yield.	Percentage of Control.		Yield.	Percentage of Control.		Yield.	Percentage of Control.		Yield.	Percentage of Control.		Yield.
	1950.	Average.		1950.	Average.		1950.	Average.		1950.	Average.		1950.	Average.	
<i>Midseason and Late Midseason Maturing Varieties for Early Planting—</i>	Bus. lb.	%		Bus. lb.	%		Bus. lb.	%		Bus. lb.	%		Bus. lb.	%	
Bencubbin	28 26	100		22 35	100		19 34	100		6 27	100		24 27	100	
Eureka	33 4	116	(7) 107	26 11	116	(7) 100	17 22	89	(6) 84	6 30	101	(7) 86	22 29	92	(6) 91
Kondut	31 15	110	(7) 106	25 4	111	(7) 99	18 54	97	(6) 76	5 14	81	(7) 85	23 7	95	(6) 89
Yalta	27 50	98	(3) 98	24 21	108	(4) 105	17 38	90	(3) 80	6 40	103	(3) 93	20 53	85	(3) 83
Difference for Significance P = .05	1-47	6%		1-42	7%		1-0	5%		1-2	16%		1-21	6%	
<i>Early Maturing Varieties for Late Planting—</i>	Bus. lb.	%		Bus. lb.	%		Bus. lb.	%		Bus. lb.	%		Bus. lb.	%	
Bungulla	25 39	100		28 2	100		22 18	100		3 41	100		26 37	100	
Koorda	29 14	114	(3) 95	26 27	94	(6) 87	20 3	80	(6) 81	2 56	80	(6) 93	23 52	90	(6) 92
Gabo	30 56	121	(4) 120	29 4	104	(4) 96	20 30	92	(5) 92	3 31	96	(4) 99	26 2	98	(4) 98
Kendee	29 23	115	(4) 117	30 24	108	(4) 97	20 45	93	(5) 84	2 34	70	(4) 96	24 34	92	(4) 98
Dowerin	25 23	99	(4) 109	21 44	78	(2) 70	21 0	94	(5) 86	2 46	75	(2) 89	22 30	85	(3) 89
Wongoody	27 9	106	(5) 119	28 22	101	(5) 94	19 0	85	(5) 95	3 54	97	102	25 42	97	(5) 95
Insignia							24 55	112		3 25	93		26 45	100	
Difference for Significance P = .05	1-4	4%		1-34	6%		Not significant	Not significant		Not significant	Not significant		0-53	3%	

N.B.—The figure in brackets indicates number of years under trial.

DISCUSSION OF RESULTS.

Midseason and Late Maturing Varieties.

The varieties in this trial have in most cases been included over six or seven years at each of the five research stations. The results, therefore, can be regarded as being a reliable indication of their yielding ability under varying soil and climatic conditions.

Reference to Table 4 showing the zones of the Western Australian wheatbelt based on the annual rainfall will indicate that for the stations in the "Early" Zone (Zone 1), the variety Bencubbin is still superior for its yielding ability. From the point of view of yield there is little to choose between the remaining varieties which have been under trial. The variety Yalta is, however, still resistant to all races of stem rust in this State, and is therefore recommended in preference to Eureka. Kondut is quite a satisfactory variety in most respects, but is susceptible to stem rust.

The results from the two research stations in the Mid-season Zone, i.e. Chapman and Avondale Research Stations, indicate that over a number of years, the three varieties, Eureka, Kondut and Yalta, are capable of yielding equally as well, and in the case of Eureka and Kondut at Avondale, and Yalta at Chapman, slightly better than Bencubbin. In view of the rust resistance of Yalta and its superior grain quality, this variety is recommended as an alternative to Bencubbin in these higher rainfall areas. Kondut, which is a late mid-season maturing variety, can be recommended in view of its potentially high yielding ability under good seasonal conditions, and its ability to yield grain of good baking quality. For the early zone, however, its recommendation is doubtful, as it only does well in this zone in years of high rainfall.

Early Maturing Varieties.

A new variety, Insignia, was included in trials on the Early Zone Research Stations. This variety will be replaced in this season's trials, by Insignia 49, which is a backcross variety similar in all respects to Insignia except that it has the rust resistance of Gabo. It is doubtful, however, if Insignia 49 will be recommended for general cultivation in view of its indifferent flour quality. It is no improvement on Bungulla in this respect, and is definitely inferior in flour quality to such varieties as Wongoondy, Gabo and Kendee.

In this Zone Bungulla still retains its position as the highest yielding variety. Of the remaining varieties, Wongoondy is equal to Bungulla at Salmon Gums, and has averaged 95 per cent. of Bungulla at Merredin and Wongan Hills over five years. In view of its strong straw and ability to produce grain of high baking quality, Wongoondy is recommended as an alternative variety to Bungulla for this zone. Wongoondy has shown a tendency to shedding under certain climatic conditions, namely, hot dry winds a few days before maturity, but this is unfortunately, a characteristic of most strong strawed free-stripping varieties. Under normal conditions it is no worse than Bungulla or Gabo in this respect.

In view of the indifferent yielding ability of Koorda, and the fact that Wongoondy has equally strong straw and better grain quality, Koorda is no longer recommended as a standard variety. It will be remembered that the variety was first recommended as a strong strawed variety suitable for light sand plain. It is now felt that there are other varieties which are more generally suited in this respect.



A plot of the wheat variety Wongoondy included in a cereal variety trial at the Avondale Research Station.

So far as yielding ability is concerned there is little difference between the two varieties, Gabo and Kendee. At Merredin, Gabo seems to be slightly superior to Kendee, but at the other stations the yields are very comparable. There have been reports from farmers that there is a tendency with Kendee, for the straw to snap just below the ear. This tendency has not definitely been confirmed on research stations.

On the other hand, Gabo has the very serious defect of being fairly susceptible to flag smut. In view of this Department's policy with regard to this disease, it can only recommend Gabo while emphasising the danger of growing flag smut susceptible varieties.

Dowerin is a useful variety, in that it is resistant to all known races of stem rust in Australia. Although it has only fair yielding ability, it would show to advantage in the event of a rust epidemic.

For Zone 2, there is a somewhat different story for the early varieties than for the mid-season varieties. With the latter the results from Avondale and Chapman were fairly comparable. With the early varieties the results from Chapman are more comparable with the results from the stations in Zone 1.

At Avondale the four varieties, Gabo, Wongoondy, Kendee and Dowerin, have outyielded Bungulla over four or five years trials. The yielding ability of Wongoondy and Gabo at this station, supports their recommendation as useful varieties for that area.

At Chapman Research Station, Wongoondy and Gabo are comparable for yielding ability, while Dowerin has been very disappointing at this station.

No information is available for Zone 3 of the wheatbelt, but it is expected that conditions in this zone would tend to favour the later maturing varieties. Rust resistance would become increasingly important in these areas.

In the following table, the recommended varieties for each zone is listed having regard to the qualifying factors for some of the varieties as mentioned above.

TABLE 4.

Maturity Group.	ZONE 1.	ZONE 2.	ZONE 3.
	Less than 15 in. Annual rainfall	More than 15 in. and less than 20 in. Annual rainfall	Over 20 in. Annual rainfall
	EARLY ZONE.	MIDSEASON ZONE.	LATE ZONE.
Midseason	Bencubbin Yalta	Kondut Bencubbin Yalta	Kondut Bencubbin Yalta
Early	Wongoody Gabo	Wongoody Gabo Dowerin	Wongoody Gabo Dowerin
Very Early	Bungulla	Bungulla	Bungulla

ACKNOWLEDGMENTS.

This opportunity is taken of thanking the farm managers and staff of the research stations for their assistance in conducting the wheat variety trials described above.

REDWATER (LEPTOSPIROSIS) OF CATTLE IN THE SOUTH-WEST.

J. E. PETERSEN, Veterinary Pathologist.

Throughout a large area of the south-west dairying district one of the serious causes of herd wastage has been the calf mortality from the disease commonly known as "redwater of calves." In many outbreaks this condition has resulted in the loss of the greater part of the year's crop of calves on the affected farms.

This loss of calves has been the most serious and most obvious effect of the disease. Adult cattle however, are also susceptible and although there appears to be no actual mortality in these, in this State, there is some economic loss through reduced milk yields of affected cows.

CAUSE AND SYMPTOMS.

The disease is due to infection by a species of bacteria known as *Leptospira*; hence the name "leptospirosis."

As the name "redwater" implies, the most outstanding symptom and usually the first observed in affected calves, is the appearance of reddish or reddish-brown urine. At the same time there is usually a high temperature and within a short while of the appearance of the redwater the affected calves become dull and somewhat unsteady in their gait if forced to walk. Interest in food and drink is often lost. If the mucous membrane of the mouth or the conjunctiva of the eye are observed at this stage they will be found to show some degree of jaundice in most cases.

The above symptoms appear from about four to 10 days after actual infection. Following the appearance of red colour in the urine the course of the disease is somewhat variable. Death may follow within one day. More commonly the redwater persists for three or four days followed by death or recovery.

The above description applies in the majority of cases. However, other cases do occur in which there are few symptoms. No red-water or jaundice is observed, only a mild degree of depression and loss of appetite.

Most of the outbreaks occurring in this State affect calves from three to 10 weeks of age. The number affected in any one herd varies greatly, from just one or two, to almost every calf. Similarly the number of deaths among affected calves can vary greatly although in most cases the mortality is quite heavy. In some countries severe outbreaks occur in adult cattle, with abortions and heavy mortalities resulting. No outbreaks as serious as this have been reported in this State, although sporadic cases of redwater do occur and some cases of sudden drop in milk production are apparently due to leptospirosis.

ANIMALS SUSCEPTIBLE.

Among farm animals cattle are the only ones which show clinical evidence of infection with leptospirosis. Pigs however, are also very susceptible to infection and although they show no illness may harbour the organism for long periods.

Sickness in humans from leptospiral infection is known to occur and it has been shown that dogs may also be infected.

SOURCE OF INFECTION.

Within a few days of infection the casual bacteria are excreted in the urine. This passage of urine containing the infective bacteria may continue for several months in the case of recovered calves or cows. In some cases and in pigs an almost permanent "carrier" state may occur, the infection persisting indefinitely.

It can be readily imagined how much contamination of a small calf paddock will occur once a few of the calves become infected. In dry, sunny weather the organisms will not persist for very long on the pasture but under wet, cloudy conditions contaminated pastures may be a source of infection for several weeks.

The contamination of pastures and yards by the urine of infected calves, cows and pigs must be considered as the main source of infection.

Some infected cows may excrete leptospirae through their milk also. This probably is of minor importance in the spread of the disease in this State but must be borne in mind as a further possible source of infection.

CONTROL.

At the present moment no satisfactory treatment for affected calves can be recommended. It appears that some of the newer types of anti-bacterial drugs available may be effective but more extensive trials with these are necessary before a definite opinion of their usefulness can be formed. Treatment by the use of vaccines and immune sera is another possibility, but has not proved entirely successful as yet where it has been attempted.

The main basis for the control of the disease must therefore be prevention.

To prevent the disease it is obvious, from the above, that the calves must be reared away from possible sources of contaminated urine. The following suggestions are made with this in view:—

1. Calf pens should be used for calves only and calves should not have access to yards or paddocks used by other animals.
 2. The drainage from other paddocks or yards, particularly from the piggery, should not pass through calf paddocks or pens.
 3. Pigs should be confined and not allowed free range over the whole farm as is the practice on many properties at present.
 4. Calf paddocks and yards around the milking shed should be well drained.
 5. Once an outbreak commences in calves all succeeding calves born should be reared well away from the infected animals. It would also be advisable to isolate those animals actually showing redwater from the remainder of the affected mob.
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AGRICULTURE IN THE KIMBERLEY DIVISION.

By W. M. Nunn, B.Sc. Agric.

From a broadcast given 9th January—Published by permission of The Australian Broadcasting Commission.

A great deal has been said and written recently about our responsibility for the vast areas of undeveloped or only slightly developed country in the Kimberley Division.



Hay baling is carried out extensively on the Liveringa flats. A pick up baler will do the job on a larger scale in future.

[Photos by courtesy K. C. Rose.]

The expenditure of large sums on large scale development of roads, harbours, railways, bridges and irrigation reservoirs, have at times been urged, and it is to be hoped that many of these schemes will, in due course, be put into effect, as there is absolutely no doubt whatever that the country is capable of far greater production given the necessary facilities.

In the meantime it is interesting to note the trend of interest among the pastoralists themselves, and to observe the efforts being made locally to improve methods and to incorporate agriculture into the scheme of things.

Up till fairly recently the majority of station owners were interested only in the utilisation of natural pastures, with little thought to the possibility of improving them, or even conserving them. Now we find quite a high proportion of owners and managers anxious to discuss the possibilities of finding new and better pasture species and ways and means of establishing them to improve carrying capacities and stock management.

On a recent trip I made, accompanied by Mr. H. K. Gibsone, our Officer-in-Charge Irrigation, assistance and advice was given to six station owners and managers who are actively engaged in developing irrigation areas. These are only small patches of course, in comparison with the huge areas grazed, but in providing green feed or lucerne hay for working horses and breeding stock, they can play a very important part in station management.

At Noonkanbah five acres of lucerne has started with great promise, with water pumped from a pool in the Fitzroy River. Mr. Beaton expects to extend to larger areas.



Pigs in a natural wallow at Glenroy Station.

[Photo: W. M. Nunn.]

Kim Rose, at Liveringa, is damming the home billabong to increase his water supply so that he can proceed next season with his plan for 20 acres of irrigated lucerne.

Bill McDonald, at Fossil Downs, has two sites on the way—one with water from a bore adjacent to the Margaret River, and one using the overflow from two 30,000 gallon tanks filled in the first instance for cattle watering purposes, by a 20ft. mill pumping from a 60ft. bore.

Mr. Millard at Gogo, has grown irrigated fodder for some years, and at Karunjie, only 100 miles from Wyndham, but two days over horrible track, Dave Rust has his irrigation area and some fine ideas for its extension and improvement.

Small beginnings, admittedly, but it is agriculture in a country where cattle grazing of an exploitive nature has, for the most part, held sway.

In addition to these private attempts, Northern Development Proprietary Limited have borrowed a bit of Liveringa, and are planning a real attempt to determine whether, or not, rice growing is a possibility on the Fitzroy flats.

Air Beef Limited have spoken for themselves on many occasions, but an aspect which they have not covered at all to my knowledge, in their publicity, is the opening for agriculture provided by the meatworks offals.

Critics of the Air Beef project have pointed to the way in which these offals have been wasted in recent seasons, but I know that the owners of Glenroy Station have some very constructive ideas about



Grain sorghum in test rows at the Kimberley Research Station.

[Photo: W. M. Nunn.]

this. They are building up their recently introduced pig population, and have set out to grow grain sorghum, and I am confident that before very long these offals will be used in, perhaps, the most economically productive manner possible.

Last year Glenroy Abattoirs handled nearly 4,000 bullocks and they hope to maintain operation at about this figure.

Using Wyndham figures for estimating purposes, 4,000 beasts give about 90 tons of blood and bone.

Four hundred acres of grain sorghum would use about 20 tons of this as fertiliser, and at only moderate yields would give sufficient grain, fed with the remaining 70 tons of protein concentrate, to maintain a herd of 200-250 sows, which could supply baconers to the meatworks at a rate of more than 2,000 per year.

Actually I am not really sure that, in the long run when we have a very greatly improved cattle industry it might not be even better for the cattle station owner to feed these concentrates to the cows and obtain better calves, and more of them to be marketed at earlier ages, but isn't it an interesting picture for the agriculturalist considering Kimberley possibilities?

Experiments at the Kimberley Research Station are proceeding satisfactorily. Cotton, rice, peanuts, sorghum and pastures can be said to give promise, but further research is required, particularly in the selection of varieties suitable to the climate, before anything can really be said concerning the economics of any one of them.



1949 dry season irrigated cotton.

(Photo. No. 649 of Station Records.)



1949-50 wet season fertiliser trial with cotton showing severe damage from grasshoppers.

(Photo. No. 713 of Station Records.)

Last year cattle were grazed experimentally, and after regular fortnightly weighings, were sent to the Wyndham meatworks for slaughter and appraisal.

The cattle, of course, provided only a means of utilising and assessing the relative values of the pastures species under trial, but it is remarkable to note the response in terms of public interest among Kimberley inhabitants, which has taken place since it has been known that cattle are actually grazing on irrigated pastures.

As the officer responsible for the development of a North-West and Kimberley Branch of the Department of Agriculture, which will place agricultural staff in these areas to undertake research and extension work, I find these evidences of interest among the local residents very encouraging indeed.

Mr. G. A. Smith, formerly of our Stock Inspection staff, has recently been stationed at Broome as Cattle Adviser, Mr. K. Fitzgerald, an agricultural graduate of the University of Western Australia, is now at the Kimberley Research Station and will shortly assume responsibility as Agricultural Adviser in the Kimberley Division.

The work of these officers will be to assist station managers generally in their attempts to improve station management, and increase station output. It is hoped that field trials might be established on private stations under their guidance, to extend the work



A. good crop of peanuts grown under furrow irrigation as a minor element trial during 1949-50 wet season.

(Photo No. 716 of Station Records.)

which has started this year at Kimberley Research Station on pastures applicable to the general range under natural rainfall conditions.

I am sure that Mr. Smith and Mr. Fitzgerald may count on an enthusiastic reception from the station people.



LARGE SCALE CHEMICAL WEED CONTROL IN CROPS

G. R. W. MEADLY, Chief Weed Control Officer.

Progress with weed control in crops on a large scale has been influenced mainly by three considerations; firstly, a suitable selective weed-killer; secondly the cost of the chemical, and thirdly the practicability of application. With a view to obtaining information along these lines some comprehensive trials have been carried out by the Department during the past season, and we have co-operated with several farmers who have undertaken extensive spraying operations on their properties. Information has also been forthcoming from demonstrations given by firms interested in the sale of chemicals and spraying equipment.

Two of the most important weeds of our cereal growing districts are *wild turnip and †wild radish, and experimental work has been directed largely against these species. We have known for some time that the 2,4-D or mormone-like weed-killers are capable of destroying these plants, but much necessary information concerning details was lacking.

Experiments were designed primarily to ascertain the minimum effective dosage of the chemical for each weed and also the quantity of solution per acre necessary to give satisfactory results. Consideration was also given to the effect of the different rates of application on both the cereal and the associated Dwalganup strain of subterranean clover.

Two proprietary lines representing the two main groups of chemicals considered most suitable for crop spraying were selected. To be precise but somewhat difficult, these were the sodium salts of 2,4-dichlorophenoxyacetic acid and 2 methyl 4 chlorophenoxyacetic acid. Fortunately, the abbreviations DCPA and MCPA are used, and the trade names are also much simpler. The sodium salts are regarded as being more selective than certain other related compounds used for weed-killing, and less likely to cause injury to cereals and clovers.

In expressing rates of application the position is made a little difficult by the fact that the proprietary lines vary in their content of active substance. In order that recommendations can be adapted to the various lines available, they are expressed in pounds or ounces of acid equivalent per acre. A powder such as Vallo, 2,4-D, contains 82% acid equivalent, or 8 1/5 pounds in ten pounds of the substance, while Methoxone is a 10% liquid containing one pound of acid equivalent per gallon. 2,4-Diweed is a 70% powder, Wilmex an 84% powder, and Weedar 77 a 45% liquid.

WILD RADISH

An experiment was carried out on wild radish using a comparatively heavily infested crop growing on sandy clay loam on the property of Mr. H. C. Rogers, Wongan Hills. The representatives of both chemical groups, DCPA and MCPA were applied at the rate of 2, 4 and 8 ounces of acid equivalent per acre. Each treatment was applied to six separate plots in order to provide the repetition necessary for accurate experimental work and a series of untreated control plots were also defined.

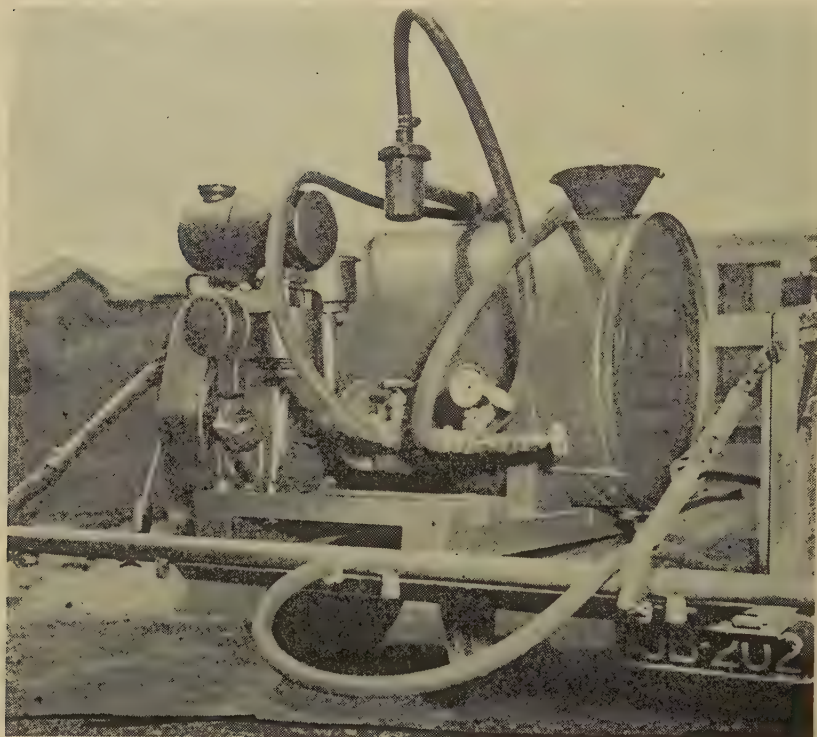
* *Brassica Tournefortii* Gouan.

† *Raphanus raphanistrum* L.



Helicopters are now being used extensively for spraying

(Photo by courtesy of Pest Control Ltd, Cambridge, London)



A low-volume boom spraying unit.



Showing the boom of the unit above.

The various treatments were applied on 1st August. The day was fine, but a gusty wind caused a certain amount of spray drift across the plots. A low volume spray unit fitted with a 24 feet boom was used with the boom set at one foot above the ground. At 50 pounds pressure and travelling at three miles per hour, the spray was applied at a rate of eight gallons per acre.

The wild radish was dense and growing strongly with leaves up to nine inches in length, but mostly somewhat smaller. The wheat was stooling freely with approximately four leaves to each stool and was about six inches in height, while the subterranean clover plants were just commencing to produce runners. Light rain fell during the night following application.

The results of this trial can be summarised as follows:—There was no marked difference between DCPA and MCPA applied at the same acid equivalent; two ounces of acid equivalent per acre reduced the quantity of wild radish but did not give a satisfactory degree of control; a few wild radish plants remained and matured on the four ounces per acre plots but would be unlikely to affect the crop yield; eight ounces of acid equivalent per acre gave virtually complete control of the wild radish. No treatment had an apparent effect on the cereal or clover, and unfortunately, plants of double gee present were also resistant.

Although the efficiency of the chemicals for the control of wild radish was clearly demonstrated, late rains made conditions very favourable for crops on the heavier soils and minimised the effect of the weed growth on grain yields. Estimates indicated improved yields on the treated plots but they did not differ sufficiently from the control plots to be statistically significant.

WILD TURNIP

A similar trial was carried out on the same property with wild turnip growing in a crop of wheat, using the chemical at the rate of two and four ounces of acid equivalent per acre, again in eight gallons of water. In this case the crop was growing on light land.



An unsprayed section of crop heavily infested with wild turnip shows as a light strip. The yield from this section was 5.7 bushels per acre compared with 11.6 bushels from the treated crop on either side.

The wild turnip was very dense in parts and ranged from small seedlings to plants six inches across while the wheat was about six inches high with three or four leaves to each stool.

Both rates of treatment proved highly effective and it was apparent that wild turnip is even more vulnerable than wild radish to the 2,4-D or hormone-like weed-killers.

Under the conditions prevailing, the four ounces of acid equivalent per acre did not give a significantly higher yield than the two ounces, but the average of the treated plots was 13.2 bushels per acre compared with 8.5 bushels per acre for the untreated control.

Some very interesting figures were obtained on light land on the property of Mr. A. J. Bell, Dalwallinu, where it was possible to compare the actual yield with the grain harvested. The chemical was applied at the rate of four ounces of acid equivalent per acre, which gave a high degree of control of the wild turnip as shown in the photograph. The relative yields of treated and untreated sections of the crop based on hand sampling were 11.6 and 5.7 bushels respectively. The corresponding figures for grain won by the header were 12 and three bushels. Included in the three bushels was approximately 15% of wild turnip seed.

A similar rate of application to a crop growing on light land on the property of Mr. J. C. O'Dea, Pithara, gave comparable results, viz., 14.9 bushels for the treated portion and 6.0 bushels for the control.

COMMENTS AND CONCLUSIONS

Experimental work and observations on large scale applications of the hormone-like weed-killers to crops during the past season have provided a considerable amount of information, with reference to Western Australian conditions.

Time of Application

The most favourable time of application necessarily varies with the season, the district and the date of seeding, but good results can be expected when the crop is about six inches high. At this stage the flush of weed germination has occurred and seedlings emerging later are unlikely to seriously affect the crop. The weeds present are relatively small which means that competition with the crop is limited, and also that they are more vulnerable to the chemical than when at a more advanced stage of growth. Again, as the crop increases in height and stools more freely it tends to protect the foliage of the weeds from the spray application.

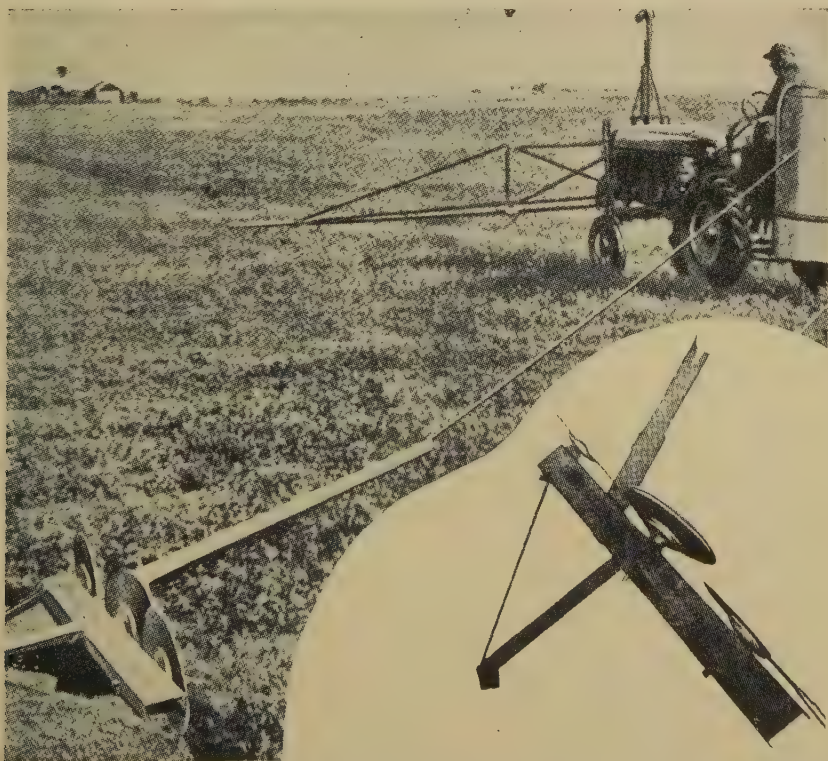
Spraying should be carried out during fine weather, although light rain soon after treatment has not proved detrimental. A strong wind is very undesirable and has been the cause of some disappointing results. It is possible to observe the drift of the spray, however, and under windy conditions it is advisable to work with a low pressure and with the boom only slightly above the crop. The pressure range used is 25 to 50 pounds per square inch.

Rate and Method of Application

The rate of application involves both the quantity of chemical and volume of solution. A high degree of control of wild radish can be obtained with four ounces of acid equivalent per acre but a somewhat heavier rate is necessary to eliminate all plants, especially if they have advanced beyond the seedling stage. Wild turnip is more susceptible and, with small plants, three ounces or even less per acre has proved sufficient.

Eight gallons of solution per acre is the rate of application employed most frequently although satisfactory results have been obtained using as little as five gallons. With such low volumes conditions for treatment must be very favourable and particular care taken to ensure even distribution. The use of such volumes, in fact the large scale spraying of crops in this State, has been made a practical possibility by the availability of low volume spraying equipment. A number of different units with booms varying in length from 24 to 40 feet are being sold.

A tractor has been found more suitable than a truck for transporting or drawing the spraying equipment as it can be driven at a governed speed, thus giving more even distribution. The usual travelling speed.



A type of marker used in Canada and copied in this State. The towing bar is about six feet long and the tow line approximates the length of the spraying boom.

is approximately four miles per hour. Various types of markers have been used to guide the driver, a satisfactory type being made from three plough discs fitted to a frame and set at the correct distance from the vehicle by means of a rope.

Suitability of Water

Questions are often asked regarding the suitability of bore and dam water for spraying purposes. The spraying units are fitted with filters to retard material likely to block the fine jets, but even with this precaution, water containing much sediment can cause delays. Again, it is inadvisable to use water containing more than 500 parts per million of calcium carbonate hardness as it is likely to precipitate the weed-killing chemical. If the water is suitable for regular drinking by humans it should prove satisfactory for dissolving the DCPA and MCPA preparations.

Cost

The economics of new projects must always be explored critically and, during the past season, cost figures have been obtained from a number of farmers who have undertaken large scale operations. Several variable factors such as length of spraying boom and distance of water carting were involved, but the cost of chemical and application, including labour and fuel, ranged from 5s. to 7s. per acre. When we take into consideration the increased yields averaging more than six bushels per acre the credit side of the operation is underlined. The cleaner product and lessened harvesting difficulties are also items that should not be overlooked. There is little doubt that many thousands of acres of weed-infested crops in Western Australia will be treated during the coming season.

ACKNOWLEDGMENTS.

Thanks are due to Messrs. H. C. Rogers, Wongan Hills; A. J. Bell, Dalwallinu; and J. C. O'Dea, Pithara, who readily co-operated and made their properties available for experiments and observations; also to Mr. B. J. Quinlivan, Botanist of the Department of Agriculture, who assisted with the experimental work.

AN EXPLANATION OF THE BEES ACT, 1930-1950

During the last session of Parliament, the Government passed an amendment to the Bees Act. The Beekeepers Section of the Farmers' Union of W.A. co-operated in drafting the bill, and the Act, when passed, had the full approval of representative beekeepers.

The need for amendment to the Bees Act, 1930, has been apparent for some years past. The system of registration provided that apiary sites were registered on a permanent basis, so that once a site was registered, it was registered for all time. Inspectors visiting an area, and working from the listed apiary sites, consequently found that a large percentage of the sites shown were no longer being used for beekeeping. The amended Act provides for registration on an annual basis, all beekeepers requiring to register as such on the 31st December each year. The opportunity was taken to introduce several other matters into the amendment, notably branding of equipment, control of neglected hives, provision of water at apiary sites, and provisions enabling the Department to have a better knowledge of the movement of migratory hives throughout the State.

A draft of the proposed amendment was submitted to the Beekeepers Section of the Farmers' Union of W.A., and the bill as approved by them was passed by the last session of Parliament.

The original Act, 1930, gave the power to the Department to take all the steps necessary for the control of disease and placed a duty upon the beekeeper to do all he could to prevent disease in his own apiary. The amending Act repeats many sections of the original Act, but in a plainer fashion and gives a better protection to the majority of beekeepers from the careless or ignorant beekeeper. To do this a beekeeper is defined under the Act in such a way that responsibility for neglected equipment and diseased hives can be brought home to the person responsible.

Under the Bees Act, 1930-1950, any person keeping bees must apply on the prescribed form for registration as a beekeeper. This registration is due for renewal on the 31st December of each year.

In addition all hives and equipment must be branded with a registered beekeeper's brand obtained from the Department of Agriculture. This brand is not subject to renewal but can be cancelled, or transferred to another beekeeper. Beekeeper's brands will consist of one letter and two numerals. It has been decided that the brands be issued in the order that the applications are received by the Department.

Power is given under the Act for officers of the Department of Agriculture to deal with abandoned and neglected hives.

The regulations under the original Act have been revoked and new regulations have been made as follows. The points to be noted are:—

Section 5.—Provision has been made that cleanliness in dealing with honey can be enforced.

Section 16.—Brands—The size of the brands has been laid down so that the one branding iron can be used to firebrand both hives and frames.

Section 19.—This section also deals with branding, setting out the duties of the beekeeper in the actual marking or branding of his hives.

Section 17.—Provision has been made for a beekeeper to keep the Department constantly advised as to where his apiaries are situated. This is a most important factor in the control of disease.

Section 18.—This section has the same purposes of Section 17.

Application for registration as a beekeeper is in card form and when filled out should be forwarded with the necessary fee to the Department of Agriculture. (It is necessary to forward the money or fee with this application for the brand.)

The application for renewal of registration as a beekeeper is to be forwarded to the Department of Agriculture every year.

When a beekeeper shifts an apiary or part of any apiary it is his duty to fill out Form 9 which will be printed in the form of a card and forward it to the Department of Agriculture. It must be emphasised that the Department, if it is to control disease in this State, must have knowledge of all shifts of bees from district to district and knowledge where the bees are situated in each district.

BEES ACT, 1930-1950.

Department of Agriculture,
Perth, 14th February, 1951.

HIS Excellency the Governor in Executive Council has been pleased to make the following regulations pursuant to the provisions of the Bees Act, 1930-1950.

A. L. McK. CLARK,
Acting Director of Agriculture.

Regulations.

Citation.

1. These regulations may be cited as the Bees Act Regulations.

Interpretation.

2. In these regulations unless the context requires otherwise—

“Act” means the Bees Act, 1930-1950;

“brand” means a registered brand issued pursuant to the provisions of these regulations and includes as well as the branding instrument the marking resulting from the use of the instrument;

“department” means the offices of the Department of Agriculture at Perth;

“fee” means the appropriate fee set forth in the Appendix to these regulations;

“honey” means honey prior to delivery to the consumer; expressions used have the same respective meanings as in the Act; regulations referred to are these regulations; sections referred to are sections of the Act.

Revocation.

3. The regulations made and published in the *Gazette* on the days shown hereunder and in force prior to the publication of these regulations are revoked:—

Gazette of 6th March, 1941, page 794;

Gazette of 18th March, 1938, page 419.

Certificates of Freedom from Disease.

(Section 14.)

4. Certificates referred to in section 14 must describe the district referred to in that section either by setting out its boundaries or by referring to it as an area comprised within an imaginary circle having a radius of five miles and having as its centre the place whence come the bees, hives, honey or appliances referred to in that section.

Extracting and Storing Honey and Preventing Spread of Disease.

5. A person shall not extract, place in containers, pack, store or otherwise handle or deal with exposed honey—

(1) unless in a structure which—

- (a) is maintained in a clean and sanitary condition;
- (b) has a constructed floor of wood, cement or other material ordinarily used for the construction of floors in structures;
- (c) is so constructed and fitted as to exclude insects, including bees and flies; and
- (d) is not used for sleeping or living purposes; or

(2) unless the container is thoroughly clean and is closed immediately upon the honey being placed in it and when closed excludes insects, dust and water.

Penalty: Twenty pounds.

Lodging of Documents.

6. Unless otherwise provided, applications made and notices given shall be lodged with the Director of Agriculture at the department accompanied by the appropriate fee, if any.

Registration and Renewal of Registration.

(Section 5.)

7. Application for registration as a bee keeper and for the issue of a registered brand shall be made in writing and signed by the applicant in Form 1.

8. A certificate of registration as a beekeeper shall, if granted, be in Form 2 and shall be issued to the applicant.

9. Application for renewal of registration as a beekeeper shall be made in writing and signed by the applicant in Form 3.

10. A certificate of renewal of registration as a beekeeper shall be made in writing and signed by the applicant in Form 4.

11. Applications for approval of the transfer, transmission or cancellation of a registered brand shall be in writing signed by the applicant in Form 5, 6 or 7 as the case requires.

12. Approval if granted of an application for the transfer, transmission or cancellation of a registered brand shall be in accordance with Form 8 and shall be handed to or posted to the applicant at the postal address shown on the application.

13. The Director of Agriculture may issue a certified copy of the certificate of registration and renewal of registration of a registered beekeeper on payment of the appropriate fee.

Register.

14. The Director of Agriculture shall cause to be kept at the department a register to be called the Register of Beekeepers and Brands and shall cause to be recorded in the register particulars of registrations, renewals of registrations and transmissions, transfers and cancellations of registrations of persons as registered beekeepers.

Search.

15. The Register of Beekeepers and Brands shall be open for inspection by any person on payment of the appropriate fee between the hours of ten o'clock in the forenoon and one o'clock in the afternoon and two o'clock and three-thirty o'clock in the afternoon on every day that the department is open for the transaction of business.

Brands.

16. The Director of Agriculture may issue distinctive symbols for use as brands, each brand comprising two numerals and one letter, the height of which numerals and letter shall not exceed one inch and be not less than one half of one inch, to applicants whose applications are granted and shall record the issue of them in the Register of Beekeepers and Brands and shall also record the transmission, transfer or cancellation of the issue of the brand and may rectify the register from time to time by cancelling the registration in his name of a brand which the Director of Agriculture is satisfied has not been used by the beekeeper in whose name it is registered for at least a period of two years.

Notice of Establishment of New Apiary or Removal of an Apiary (Section 5A).

17. Notice required by section 5A to be given by a beekeeper or registered beekeeper of the establishment of a new apiary or the removal of the whole or part of an apiary from an apiary site to another site shall be given in writing signed by the beekeeper or registered beekeeper in Form 9.

Notice of Sale of Apiary (Section 5C).

18. Notice required to be given by section 5C of sale by a person shall be given in writing signed by the person in Form 10.

Branding of Hives and Equipment.

19. (1) A registered beekeeper must brand his hives and beekeeper's equipment with his registered brand.

(2) The brand may be burnt in, acid etched, embossed, stamped or carved but so that the brand is of a depth of one-eighth of an inch below the surface branded where that surface is of wood.

(3) Hives shall be so branded that successive owners' brands shall appear immediately below the next preceding owner's brand commencing in the top left hand corner of an external face of a side of the hive.

(4) Every person who at the date of the coming into operation of the Bees Act, 1930-1950, namely the fifth day of January, 1951, is a beekeeper shall within three months of that date brand hives of which he is the owner on that date.

(5) Every beekeeper who on any day after the coming into operation of the Bees Act, 1930-1950, namely the fifth day of January, 1951, acquires beehives shall brand each of his hives forthwith on acquiring it.

(6) A person, who brands or marks a hive or beekeeper's equipment with the registered brand of another person without the latter's authority commits an offence.

(7) A person who—

(a) alters, defaces or otherwise renders undistinguishable a registered brand or the marking made on a hive or beekeeper's equipment by the use of a registered brand or

(b) knowingly permits any such act to be done by a person over whom he has control,

commits an offence.

Abandoned and Neglected Bees and Beehives.

(Section 5F.)

20. (1) Prior to taking possession of any bees or beehives pursuant to the power conferred upon him by section 5F an inspector shall obtain the approval of his doing so from the Director of Agriculture.

(2) Where an inspector takes possession of bees or beehives pursuant to that section and approval was obtained he may with the approval of the Director of Agriculture take such measures as may be necessary to cure disease if there be any, and having cured the disease may sell the bees, bee combs, honey and hives and pay the proceeds of the sale, after meeting the costs thereof, into the Consolidated Revenue Fund, but if there be disease and it is not possible to cure it economically having regard to the relative expenses and probable return from sale, he may destroy the bees or hives as the case may be.

General Penalty.

21. Except where any other penalty is provided in these regulations, the penalty for a breach of any of these regulations shall be five pounds.

Regulation 7.

Western Australia.

Bees Act, 1930, as amended.

(Section 5.)

Form 1.

APPLICATION FOR REGISTRATION AS A BEEKEEPER.

To the Director of Agriculture,
Department of Agriculture,
Perth.

I (a) of (b)

hereby apply for registration as a beekeeper and for the issue to me of a registered brand pursuant to the provisions of the abovementioned Act.

The information and particulars required to be given by paragraphs (a) and (b) of subsection (5) of section 5 are as follows:—

(c) Apiary Site.	No. of hives.	Description of brand on hives— describe the latest brand if more than one.

Dated the day of 19 .

Signature of Applicant.....

Fee on application for registration—

	s.	d.
for first 25 hives or lesser number	2	6
for every 25 hives or lesser number thereafter	1	0
Fee on application for registered brand	7	6

(a) Full name. (b) Address. (c) Give particulars of location including approximate distance and compass bearing from the nearest town, name and postal address of the owner of the land and lot or location number of the land.

Regulation 8.

Western Australia.
Bees Act, 1930, as amended.
Section 5.
Form 2.

CERTIFICATE OF REGISTRATION.

I hereby certify that (a) _____ of (b) _____
is registered as a beekeeper for the period shown hereunder as required by the
abovementioned Act and that the registered brand issued to him is as shown
hereunder.

Period of registration:

From the	day of	19 .
to the	day of	19 .

Description of registered brand:

Dated the _____ day of _____ 19 .

Director of Agriculture.

Note.—This certificate does not authorise the establishment or maintenance
of an apiary contrary to the provisions of the Act in general or section 5B in
particular.

Subsection (4) of section 5 is as follows:—

(4) Every registered beekeeper shall on or before the thirty-first
day of December of every year apply for the renewal of his registration
as a registered beekeeper.

(a) Full name. (b) Address.

Regulation 9.

Western Australia.
Bees Act, 1930, as amended.
Section 5.
Form 3.

APPLICATION FOR RENEWAL OF REGISTRATION AS A BEEKEEPER.

To the Director of Agriculture,
Department of Agriculture,
Perth.

I (a) _____ of (b) _____
being the holder of registered beekeeper's certificate numbered (c) _____
hereby apply for renewal of registration as a beekeeper.

Dated the _____ day of _____ 19 .

Signature of Applicant.....

(a) Full name. (b) Address. (c) Quote No.

Fee on application for renewal of registration—

for first 25 hives or lesser number—2s. 6d.;
for every 25 hives or lesser number thereafter—1s 0d.

Regulation 10.

Western Australia.
Bees Act, 1930, as amended.
Section 5.
Form 4.

CERTIFICATE OF RENEWAL OF REGISTRATION AS A BEEKEEPER.

No. _____

I hereby certify that—

(a) _____ of (b) _____
being the holder of registered beekeeper's certificate numbered (c) _____ has
renewed registration as a beekeeper as required by the abovementioned Act for
the period commencing on the _____ day of _____ 19 , and ending
on the thirty-first day of December, 19 .

Dated the _____ day of _____ 19 .

Director of Agriculture.

(a) Full name. (b) Address. (c) Quote No.

Regulation 11.

Western Australia.
Bees Act, 1930, as amended.
Form 5.

APPLICATION FOR APPROVAL OF TRANSFER OF REGISTERED BRAND.

To the Director of Agriculture,
Department of Agriculture,
Perth.

Approval is sought for the following transfer:—

Full name, address and signature of proposed.		Description of brand.	Date of application.	Date of approval and signature of Director of Agriculture.
Transferor.	Transferee.			

Fee: 2s. 6d.

Regulation 11.

Western Australia.
Bees Act, 1930, as amended.
Form 6.

APPLICATION FOR APPROVAL OF TRANSMISSION OF REGISTERED BRAND.

To the Director of Agriculture,
Department of Agriculture,
Perth.

Approval is sought for the following transmission:—

Full name, address, signature and capacity in which the applicant applies, e.g., as executor of the Will or administrator of the estate of a deceased registered beekeeper.	Description of brand.	Date of application.	Date of approval and signature of Director of Agriculture.

Fee: 2s. 6d.

Regulation 11.

Western Australia.

Bees Act, 1930, as amended.

Form 7.

APPLICATION FOR APPROVAL OF CANCELLATION OF REGISTERED BRAND.

To the Director of Agriculture,
Department of Agriculture,
Perth.

Approval is sought for the following cancellation:—

Full name, address and signature of applicant, and grounds of application.	Description of brand	Date of application.	Date of approval and signature of Director of Agriculture.

Regulation 12.

Western Australia.

Bees Act, 1930, as amended.

Form 8.

To (a)
(b)

You are hereby notified that your application dated the _____ day of _____ 19____, for the transfer/transmission/cancellation of the registered brand described hereunder was approved on the _____ day of _____ 19____.

The brand is now registered in the name of _____ of _____

Description of the registered brand:—

Dated the _____ day of _____ 19____.

Director of Agriculture.

(a) Name. (b) Address.

Regulation 17.

Western Australia.
Bees Act, 1930, as amended.
Section 5A.
Form 9.
Notice.

To the Director of Agriculture,
Department of Agriculture,
Perth.

I (a) _____ of (b) _____ being
a (c) beekeeper/registered beekeeper holding certificate of registration No. _____
hereby notify the Director of Agriculture that on the _____ day of
19 _____, I established a new apiary at (d) _____

The new apiary so established comprises (e) _____ hives.

Particulars of the latest registered brands appearing on those hives are as
follows:—

(f) _____ or

I removed from apiary site (d) _____

(c) the whole/part of the apiary then at that apiary site to a site at (d) _____

The hives so removed were the following:—

(g) _____ leaving at the former apiary site
the following hives:—

(h) _____
Dated the _____ day of _____ 19 _____

Signature _____

(a) Full name. (b) Address. (c) Strike out inapplicable words. (d) Give particulars
of location including approximate distance and compass bearing from the nearest town,
name and postal address of the owner of the land and lot or location number of the land.
(e) State number. (f) Here show the brands on the hives, e.g., 5 hives branded 1B2; 3 hives
branded 3C4. (g) Show the number of hives and the latest brands on them. (h) See (g)
above or insert "nil" if all hives so removed.

Regulation 18.

Western Australia.
Bees Act, 1930, as amended.
(Section 50.)
Form 10.
Notice.

To the Director of Agriculture,
Department of Agriculture,
Perth.

I (a) _____ of (b) _____
being a (c) beekeeper/registered beekeeper holding certificate of registration
No. _____ hereby notify the Director of Agriculture that on the _____ day
of _____, 19 _____, I sold to (d) _____ of (e) _____

(f) the whole/part of the apiary then at apiary site (g). _____

The hives so sold were the following:—

(h) _____
leaving at that apiary site the following hives:—

(i) _____
Dated the _____ day of _____ 19 _____

Signature _____

(a) Full name. (b) Address. (c) Strike out inapplicable words. (d) Full name.
(e) Address. (f) See (c) above. (g) Give particulars of location including approximate
distance and compass bearing from the nearest town, name and postal address of the owner
of the land and lot or location number of the land. (h) Show the number of hives and
the latest brands on them. (i) See (h) above or insert "nil" if all hives so sold.

APPENDIX.

Fees.

Fee on application for registration as a registered beekeeper:—

	s.	d.
For the first 25 hives or lesser number owned by the applicant	2	6
Plus for every 25 hives or lesser number thereafter	1	0
Fee on application for registered brand	7	6
Fee on application for transfer or transmission of registration of brand	2	6
Search fee	2	0
Certified copy of certificate of registration	2	6



SPRAYING TO CONTROL PRE-HARVEST DROP IN WASHINGTON NAVEL ORANGES.

L. T. JONES, Senior Plant Research Officer.

INTRODUCTION

Fertilisers, fungicides and insecticides are now accepted as essential aids to the production of commercial crops. Within the last 20 years a new list of substances has been added to the materials that can increase crop returns. Collectively, these are known as "growth regulating substances" because when applied in correct amounts and in a suitable manner they will inhibit, increase, or alter in various ways the subsequent growth of the treated plants.

Some of the more spectacular and better known applications of the use of these so-called "plant hormones" are the production of seedless fruits, the rooting of cuttings, the prevention of pre-harvest fruit drop and the development of the so-called selective weed killers. This article deals solely with the observed responses in an experiment at Upper Swan, using a growth regulating substance termed 2,4-dichlorophenoxy acetic acid (usually shortened to 2,4-D) at a concentration of 20 parts per million for the prevention of pre-harvest drop in Washington Navel oranges.

The prevention of pre-harvest drop in apples using a spray of alpha-naphthalene acetic acid has already been demonstrated in local experiments.

Summary of Previous Investigations

Research work initially carried out in America has demonstrated that 2,4-D sprays have materially reduced the drop of mature citrus fruit. Concentrations of between 5 and 25 parts per million of 2,4-D proved effective and higher concentrations than these are not recommended because of possible undesirable effects on fruit quality. Even at low concentrations 2,4-D spray may cause leaf distortion when applied to actively growing shoots. This leaf distortion may be minimised by spraying between leaf growth flushes.

In some instances where fruit was held on the tree long after the period of commercial harvest, it was found that 2,4-D sprays were effective in reducing fruit drop for a total period of at least six months.

It is assumed that the growth regulator 2,4-D reduces fruit drop by delaying the aging of the separation layer which holds the fruit to the stem.

Material Used in Trial

The commercial preparation used in this trial was a selective weed killer called "Weedone" which is an oil base preparation of the ethyl ester of 2,4-D and containing approximately 10 per cent. of the free acid equivalent.

It is not meant to imply that this preparation has advantages or otherwise over other preparations that are on the market. The material was on hand when the trial was commenced and its use was mainly a matter of convenience. No attempt was made to compare its efficiency with any other commercial preparations of 2,4-D.

To obtain the desired concentration of about 20 parts per million of 2,4-D, $1\frac{1}{2}$ ounces of "Weedone" was added to 50 gallons of water.

The importance of correct concentrations when using this spray is illustrated by the fact that "Weedone" at the rate of 6 ounces to $7\frac{1}{2}$ gallons of water may be used as selective weed killer.

Experimental Methods.

On the 1st July, 1949, 15 reasonably uniform Washington Navel orange trees were selected from two adjacent rows in the orchard of Mr. J. E. Anderson at Upper Swan.

Ten trees were then sprayed with 2,4-D at a concentration of approximately 20 parts per million. This concentration was obtained by using $1\frac{1}{2}$ ounces of "Weedone" (containing approximately 10 per cent of 2,4-D) in 50 gallons of water.

A power spray was used and about four gallons of spray was needed to thoroughly drench each tree. The weather was sunny and a good drying wind was blowing at the time of application.

Five of the selected trees were left unsprayed to serve as controls.

Very little new growth was present on the trees at the time of spraying and therefore much leaf distortion was not to be expected. All fallen fruit was picked up from under the trees after spraying.

Heavy rain fell that night about eight hours after applying the spray. As there was some doubt as to the effect of heavy rain so soon after the spray application and to test the effect of a second spray, five of the 10 treated trees were again sprayed with 2,4-D at 20 parts per million on the 18th July, 1949, under favourable weather conditions.

Counting of Fallen Fruit

The first count of fallen fruit was made on the 15th July, and from then on regular counts were made at from three to five day intervals until harvest time on the 15th August.

The numbers of—

- (a) fallen fruit;
- (b) harvested fruit; and
- (c) total fruit on the tree,

at the time of the first spraying are tabulated for each of the 15 experimental trees.

After it was too late to remedy the omission it became apparent that a division of fallen fruit into sound and rotten would have given more precise information.

Also some exact figures on the percentage of "buttons" remaining on the picked fruit as between treated and untreated trees would have been more convincing than observations only.

2.4-D SPRAY ON WASHINGTON NAVEL ORANGES.—J. ANDERSON, UPPER SWAN.

SUMMARY OF FALLEN FRUIT—HARVESTED ON 15TH AUGUST, 1949.

Tree Number.	Fallen Fruit.	Fruit Harvested.	Total Fruit.	Fallen Fruit.
TREATMENT A.—Sprayed 1st July only.				
1	65	639	704	% 9.2
2	28	407	435	6.4
3	84	969	1,053	8.0
4	48	577	625	7.7
5	12	340	352	3.4
Average	47	586	633	7.5
TREATMENT B.—Sprayed 1st July and 18th July.				
6	20	376	396	5.1
7	29	527	556	5.2
8	45	446	491	9.2
9	66	454	520	12.7
10	62	413	475	13.1
Average	44	443	487	9.1
TREATMENT C.—Control, not sprayed.				
11	75	319	394	19.0
12	139	439	578	24.0
13	113	363	476	23.7
14	138	410	548	25.2
15	238	448	686	34.7
Average	140	396	536	26.2

Summary of Results and Observations

(1) 2,4-D spray at 20 parts per million had a marked effect in arresting pre-harvest drop of Washington Navel oranges on this property. Figures based on the number of oranges on the tree at the time of spraying showed that treated trees lost an average of 8.3 per cent. as windfalls, while the untreated trees lost an average of 26.2 per cent. as windfalls.

(2) Windfalls from the untreated trees were mostly sound fruit while those from the treated trees were mostly unsound and mouldy. This means that the 2,4-D spray was fulfilling its function of keeping the separation layer immature, but that the fruit that fell did so because it rotted and pulled away from the stalk. It is obvious that had only sound windfalls been counted the difference due to treatment would have been accentuated.

(3) The treated fruit would apparently have hung on the tree for a considerable period after the actual time of harvesting. However, the rotting of the oranges on the tree during the wet weather made it imperative to harvest earlier under these conditions to avoid excessive losses.

(4) When picking the fruit it was observed that fruit from untreated trees lost their "buttons" very easily while the treated trees had a very high percentage of "buttons" still remaining on the fruit.

(5) A second spray apparently had no better effect than a single spray in reducing the percentage of windfalls.

(6) No obvious distortion symptoms could be seen on new leaves as might have been expected. However, new growth was fairly sparse at the time of application of the spray.

(7) With this particular spray heavy rain eight hours after application did not nullify its effects.

Possible Commercial Benefits

The cost of the 2,4-D material used in this trial worked out to about a penny per tree. There is a great saving in eliminating a high proportion of windfalls which, of course, cannot be marketed. In this trial the windfalls saved would amount to about a case per tree.

Another possible economic benefit is that in the past it has been the practice to pick all the crop immediately it is apparent that a heavy windfall loss is going to occur. It is usually found that a low market price is obtained at this period because a glut has been caused by other growers being forced to follow the same procedure. Thus the use of 2,4-D spray would tend to eliminate gluts caused by forced harvesting.

Another important consideration is that the use of this spray would enable growers to spread their picking over a longer period than would otherwise be possible. This fact would allow more

freedom in the choice of markets and the avoidance of gluts could be more easily controlled. Where labour is short the use of this spray could appreciably extend the picking season and thus place less strain on the labour available.

The greater retention of "buttons" observed amongst the sprayed fruit would be an advantage in marketing.

Acknowledgments

Thanks are due to Mr. J. E. Anderson, of Upper Swan, for allowing the experiment to be conducted in his orchard, and for his considerable assistance in the conduct of the trial.

Reference

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GENETICS AND ANIMAL BREEDING.

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FROM the time that Bakewell, in the latter half of the 18th century, commenced a breed improvement plan with cattle, sheep and horses including such devices as inbreeding and the use of an occasional wide outcross if it appeared necessary to obtain a desired character not present in the breed, there have been men showing a keen interest in animal breeding. Bakewell also instituted a system of progeny testing of rams by leasing them to surrounding farmers with the option of re-purchase of any whose progeny appeared outstanding. He and his disciples laid the foundations of the present pure breeds of livestock by using such principles as "Like produces like or the likeness of some ancestors; inbreeding produces prepotency and refinement; breeding the best to the best." These principles were sound and still hold good but our present state of knowledge is such that certain refinements to these general principles can be advanced which take more of the guess work out of animal breeding. For this advancement we are indebted to Gregor Mendel, an Austrian monk, and to the scientists who followed after him and founded the science of genetics.

Genetics is the science which seeks to account for the resemblances and differences that occur between animals related by descent.

Mendel experimented with sweet peas and in 1865 read a paper setting out the findings of several years of research and postulating five hypotheses to explain the results that occurred. These hypotheses with minor amendments and additions now form the basis of genetic theory which is common to both the plant and animal kingdoms.

Unfortunately Mendel's work did not immediately attract much attention and it was not until the turn of the century that his paper was rediscovered and its significance realised. Mendel's hypotheses were then soon fitted into the cellular conception of living matter made possible by the invention of the microscope. Numerous workers have since experimented both in the fields of plant and animal breeding and from the aspect of pure genetics and great advances have been made.

It is now known that the genes, as the units of inheritance are called, are situated on the chromosomes which occur in pairs in each cell nucleus. Most farm animals contain at least 20-30 pairs of chromosomes and some estimates place the numbers as high as 48 pairs in dairy cattle. The genes are carried on the chromosomes perhaps rather like beads on a piece of string and so can not move their position with respect to one another and can be identified by their action and by their position on the chromosome.

Each gene is responsible for a single function in the body and such characteristics as milk production and butterfat percentage are the result of the interrelationship of probably at least a dozen genes and perhaps many more. Other characteristics such as hornlessness in cattle can be brought about by the presence of a single gene.

The chromosomes which an animal possesses come to it from its parents at the time of its conception, one of each pair coming from each parent. It is important to realise that the genes also pass to it at this time and that they retain their identity. A gene's action in the one individual is influenced by the gene with which it is paired and by the remainder of the genetic make-up of the individual but the gene retains its identity and can be passed on to the next generation unaltered. Thus the genetic or breeding worth of an animal is determined before it is born and any characters which it acquires during its lifetime as a result of environmental influences can not be passed on to succeeding generations. Similarly the potential producing ability of an animal is determined at the time it is conceived and no amount of attention to good feeding practices and care will permit it to produce at a level above that potential.

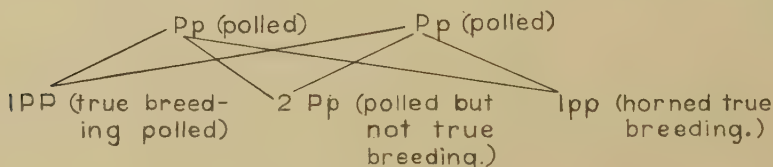
The gene at any particular place on the chromosome may take one of several forms, the different forms occurring being the result of mutation at some time during the evolutionary scale. It is known that some genes exist in as many as half a dozen different forms each recognisable by the effect it produces.

A gene may be dominant in which case it produces its full effect whatever the state of the gene with which it is paired. Such a gene is that producing the polled character in cattle and any animal possessing one such gene will be hornless.

In mating one animal true breeding for polledness to another horned animal we have the following position.



The animal resulting from this cross will be polled but will not be true breeding for the condition. Two such animals mated together will produce the ratio of three polled to one horned animal; the horned animal and one third of the polled animals will be true breeding and the remaining two polled animals will not be true breeding because of the presence of the gene for horns in a recessive condition which would remain hidden until it occurred in an individual without the repressing influence of the gene for polledness.



A gene may be fully recessive in which case it does not influence the characters of the animal in which it occurs until such time as it is linked up with a similar recessive gene. Many recessive genes are harmful and a number are even lethal when they occur in homozygous form—that is when both genes at the one point on each of the chromosome pair are the same. An example of a lethal gene is the one in Dexter-Kerry cattle producing dwarfness when combined with the normal gene and a bulldog calf when homozygous.

A gene may be somewhere between the two extremes of dominance and recessiveness in which case a degree of blending takes place. For example roan coat colour in cattle is caused by the presence of a gene for red coat colour and a gene for white coat colour present in the same animal. Roans are never true breeding and mating two roans can produce both reds and whites in addition to roans.

Probably many of the genes of commercial importance blend to a certain extent and may be additive so that a homozygous animal with a "double dose" of a particular gene will produce the effect to a greater extent than one with only a single dose of the gene. To further complicate matters many genes produce their effect only in the presence of another gene at a different point on the chromosome

The direct mode of inheritance of almost all of the commercially important characteristics of farm animals have yet to be worked out in detail by the geneticist. In the meantime many recommendations can be made which will make the task of the animal breeder rather easier.

It is the role of the animal breeder, understanding the fundamental part played by the gene, to mate animals having a large number of genes producing the desirable characters which he wants spread more widely in his herd and to prevent animals possessing a large number of undersirable genes from leaving offspring.

Hence firstly he must adopt some form of measurement to determine as nearly as possible which animal has the greatest number of desirable genes and he must keep in mind that the greater the number of traits for which he is selecting the more difficult will be selection for any one of them.

Measurement of the worth of a dairy cow can be done by some form of herd testing to determine just what each cow produces both in milk and in butterfat percentage. Unfortunately few breeders can afford to feed at an optimum level and this must remove a lot of the advantage of the animal with the high breeding potential as compared to another with a lower potential producing ability. By reducing the margin of the high producer, adverse environment—including low feeding—increases the difficulty of determining just which cow is the most desirable and so slows down rate of improvement.

Factors other than production which should receive some attention when one is determining which cow should be used as a breeder include length of life, freedom from disease of an hereditary nature and temperament.

Selection of the bull to use as a herd sire is rather more difficult as the bull does not himself produce—as distinct from a beef breed—the characters desired in his progeny. Hence in selecting a dairy herd sire his ancestors or pedigree, with particular reference to the first and second generations may be considered as may his full and half sisters if any are available. More particularly his progeny, if and when they enter test, may be used as a measure of his breeding worth. Once a bull has ten or more daughters which have completed a lactation under test, little attention need be paid to his pedigree in determining his desirability as a herd sire.

In evaluating the various factors to determine the desirability of a cow or bull to be used for breeding it is important to distinguish between characters which are largely inherited and others in which environment has played the main part. Obviously accident or injury are environmental influences and allowance should be made for them in evaluating a cow's worth. Disease is almost entirely environmental although possible a weakness permitting entry of the organism may be inherited, and little selection against the offspring of animals with low production as a result of disease need be practiced. Some

other factors such as coat colour and presence or absence of horns are almost entirely due to inherited characters and so where they are economically important much emphasis should be placed upon them in determining the animals to use for breeding.

Most of the economically important characteristics of the dairy cow are influenced by both environment and heredity and one of the most important tasks now facing the animal geneticist is to measure the importance of each under varying circumstances for such characters as milk production, fat percentage, persistency, good dairy temperament and length of useful life. A start has been made in both New Zealand and America and some interesting findings have been published. For instance most investigators agree that production of milk is in the order of 25-30 per cent. inherited and only the inherited portion may be expected to be passed on from one generation to the next. This means that if a cow produces 100 lb. above the breed or herd average and she is mated to a bull of equal worth her daughters can be expected on the average to produce only 25-30 lb. above the breed or herd average and the remainder is lost in what is known as regression to the breed average. *Butterfat percentage is more highly inherited and so a greater amount of a high test in one generation may be expected to be passed on to succeeding generations.*

Other factors such as persistency, temperament and length of life are known to be inherited but the degree is not known. From a practical point of view the thing to remember is that only characters that are inherited through the gene should be taken into account and that the more highly a character is inherited the more emphasis should be placed upon it so long as it is economically sufficiently important.

SYSTEMS OF BREEDING.

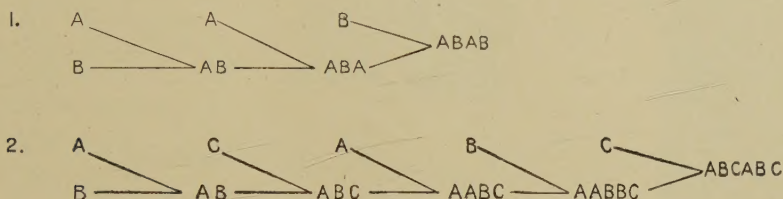
In addition to selecting animals which as individuals are desirable parents of the next generation, the herd manager may practice one of several methods of breeding, each of which has much to commend it in certain circumstances. These systems may be divided firstly into outbreeding, inbreeding and grading up and into the subclasses within the first two divisions. Here we will briefly discuss the genetical implications of each of the various systems of breeding and some of the applications.

Outbreeding means the mating of unrelated animals, or in practice animals which have no common ancestor in the preceding five or six generations.

It may be crossbreeding which is the mating of animals of different breeds. Crossbreeding produces a phenomenon known as heterosis or hybrid vigour which as the latter name implies results in an added vigour in the progeny. Such animals grow more rapidly and have been shown in some experiments in America to produce more milk and butterfat than would be expected by averaging the butterfat level of the dam and the calculated level of the sire. It has been shown that it is still desirable to have animals which are

individually desirable although this is not as important as with inbreeding. The chief objection to the system is that the progeny, which are crossbreeds, if used for breeding produce a very wide range of types in the next generation.

A variation is to use two or even three breeds of bull and to mate breeds according to a definite cycle. With two and three breeds this would be respectively:—



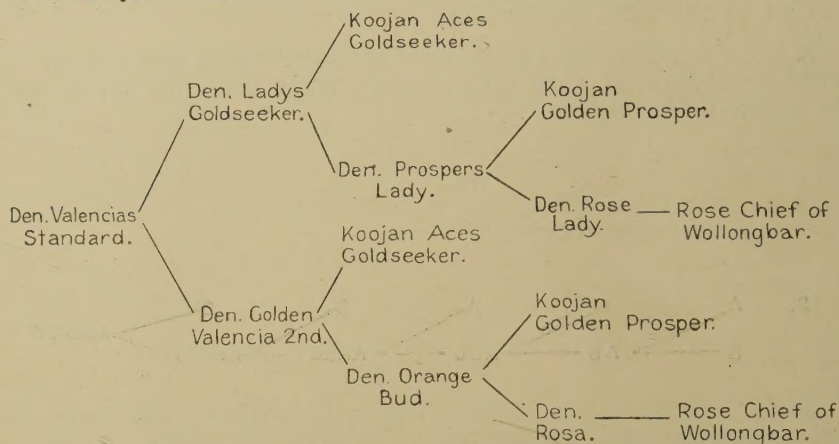
Such systems retain hybrid vigour throughout and have been shown experimentally in America to be very successful. A practical difficulty is that two, or even three, bulls must be kept and few farms are big enough to warrant this. *Care must be taken to prevent mating becoming haphazard and on no account should a crossbred bull be used as a sire.*

Outcrossing may also be carried out within the one breed, particularly by mating two animals which are themselves inbred but which are not related to each other. Some degree of hybrid vigour is obtained by this means but here again does not reappear in the second generation.

Inbreeding is the mating of animals which are more closely related than the average of the breed from which they come and for practical purposes can perhaps be taken in the common breeds of dairy cattle to be the mating of animals which have common ancestors within the first five or six generations. Inbreeding to any degree is usually frowned upon by the practical animal husbandman as it is believed to result in a lack of vigour, smaller body size and consequent lowered production. Whilst it is true that this has frequently been a consequence of inbreeding it is equally true that deterioration does not always follow on inbreeding. The role of inbreeding is to fix whatever characteristics the line of animal has: if the animals with which the breeder starts are of poor or even medium standard then the result will not be favourable. If, however, the initial animals are good and a reasonable amount of culling can be practised inbreeding should produce a strain of even appearance producing at a high level. With inbreeding in the early years it is always necessary to cull at a high level to rid the herd of animals in which undesirable recessives become fixed.

In the example shown Koojan Aces Goldseeker and Koojan Golden Prosper are themselves inbred and the total inbreeding of the bull Denmark Valencias Standard is 22.97 per cent. which is rather high. The Valencia strain of cattle has been particularly valuable in building up the Denmark Stud to its present position amongst the leading herds of the State and is at present the highest

producing strain in the herd. Most Guernsey cattle in W.A. are inbred to a greater or lesser extent due originally to the influence of the Koojan Stud.



An Example of Inbreeding.

Linebreeding is a special form of inbreeding in which inbreeding is kept at a minimum in keeping with having the blood traced back to one or possibly two very desirable ancestors. By this means the characteristics of a promising individual can be passed on through a number of generations and, because inbreeding is kept relatively low, greater selection can be accorded to other desirable traits. Linebreeding is a sound system of breeding and is very desirable particularly when an outstanding proven bull has been obtained, for example, by importation from overseas.

The third system of mating mentioned earlier is known as Grading up and is used in the large percentage of Grade Herds. A pure bred bull is used and mated to cows of various and mixed breeds. Another pure bred bull of the same breed is used on the progeny and after five or six generations of grading up by this means, the stock is to all intents and purposes similar to pedigreed stock of the same breed. To obtain further improvement one has to look for a bull with excellent production backing or, better still, a proven bull whose daughters have performed creditably. The possession of a pedigree is not of itself an indication that a bull will further raise production.

It is realised that the main problems confronting the dairy farmer today are not problems of breeding. Disease has such a high incidence in many herds that little attention can be given to selection of the higher producing animals. Further, few herds are fed at a level sufficiently high to produce to anything approaching the maximum. These two problems have to be tackled in conjunction with animal breeding and have to be solved before breeding can make much headway.

Where and when feeding is at a high level and culling for production can be practised, attention to selection of desirable animals combined with progeny testing of the herd sire and a definite system of breeding can produce a marked improvement in average production of the herd and less variability between individuals.